BTO Research Report No. 485

Predicting the impact of future agricultural change and uptake of Entry Level Stewardship on farmland birds

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1. EXECUTIVE SUMMARY

1. Environmental Stewardship (ES) was launched in England in 02005 with three components; Higher Level Stewardship (HLS), Entry Level Stewardship (ELS) and Organic Entry Level Stewardship (OELS). The work reported here is intended to inform the ongoing review of ES but focuses on ELS for which uptake data are more extensive. From the outset ELS had four broad objectives (improving water and soil quality, enhancing farmland wildlife, maintaining landscape character and protecting historic environment). The conservation on farmland birds is central to one of these objectives and the scheme is a key tool for the delivery of the farmland bird PSA target. The work reported here has seven distinct objectives: (i) to update the evidence base and identify remaining knowledge gaps of resource requirements and causes of decline of farmland birds; (ii) to review knowledge on practical measures to improve quality of ELS options; (iii) to review knowledge on optimal ways to deploy options in the landscape; (iv) to review knowledge for past value of set-aside for farmland birds and potential impact of its loss; (v) to assess the proportion of landscape required under specific management to produce a population increase in relation to current availability of such habitat under ELS; (vi) to predict likely future trends in the farmland bird index in relation to a small number of future scenarios; and, (vii) to make recommendations for future research and highlight implications for the design and operational delivery of the scheme. In the following summary we highlight, in bold, key findings with research or policy (operational or practical) implications.

2. The first objective was to update the evidence base and identify remaining knowledge gaps of resource requirements and causes of decline of farmland birds. Comprehensive searches of literature databases revealed over 70 new references of direct relevance (since a previous review in 2001). Many of these related to five species; Lapwing *Vanellus vanellus*, Skylark *Alauda arvensis,* Yellow Wagtail *Motacilla flava*, Reed Bunting *Emberiza schoeniclus* and Corn Bunting *Milaria calandra*, and most reinforced findings of previous studies. The exception to this was Yellow Wagtail for which a great deal more is now known about its ecology in arable farmland. In particular, a mid-season shift in the habitat associations, from cereal to potatoes, suggests a lack of suitable breeding habitat in late summer may reduce productivity and contribute to the observed population decline. **There may be a need to develop agri-environment scheme options that provide late summer nesting habitat for yellow wagtails in a similar way to the in-field plot approach for Lapwing and Skylark.** In addition to single species studies, there has been considerable research on birds in grassland habitats. This has highlighted the importance of interactions between food abundance (high in tall complex swards) and food accessibility (high in short even swards) in grasslands. This work suggests the optimal foraging habitat in grassland would be a mosaic of different sward heights. **The principle questions remaining to be resolved are how to best deliver this sward heterogeneity in grassland through agri-environment options, and at what spatial scale**

3. The aim of objective 2 was to identify possible modifications to existing prescriptions that may improve their measurable benefits for farmland birds. As for objective 1, this was addressed through a literature search and expert opinion. **The two most important option modifications suggested are: (i) an extension of winter food resource options (stubbles EF6, EG4, EG5 and wild bird cover crop EF2, EF3, EG2) in to late winter (i.e. beyond February 15th); and, (ii) management of grass margin options to increase structural heterogeneity, particularly opening up the sward to improve accessibility of prey.**

4. Objective 3 reviewed current knowledge on the extent to which three aspects of option deployment can influence the effectiveness with which they deliver resources to birds: (i) extent or scale, (ii) configuration (size and shape of options) and (iii) context (local and landscape effects). **There were very few studies to draw on that addressed the issues of quantity, size, shape or the influence of local or landscape context of habitat patches on**

effectiveness of resource delivery for birds. The most valuable studies on scale (quantity or size of patches) relate to providing winter food and suggest that, for skylark, approximately 10ha of stubble per 1-km^2 is needed to stem the population decline and winter use will be maximised by creating these resource patches more than 1km apart. The main effect of shape is likely to be through influencing edge: area ratios on patches which may be important in determining predation rates. The effect of context on habitat use is complex; margins near good quality hedgerows may offer higher value for birds, particularly in summer but hedgerows and margins may also be sources of predators for ground nesters. At the landscape scale, the value of a given habitat may be enhanced by creating it where it also serves to enhance heterogeneity e.g. arable areas in grassland. However, areas of high quality habitat in poor quality landscapes may also serve as predator traps. **Issues such as the impact of scale, configuration and context on the effectiveness of agri-environment scheme options could be addressed by linking the monitoring of ELS with targeted research.**

5. Objective 4 was designed to investigate the potential impact the loss of set aside on birds, as a habitat that provides nest sites for some species and food in summer and winter for many species. We related data on the population trends of the nineteen Farmland Bird Index species to temporal changes in the availability of set-aside for the period 1994-2005. The population trend for all Farmland Bird Index species was significantly positively correlated with the availability of set-aside in the same year, although individual trends were significant for only two species, Lapwing and Linnet *Carduelis cannabina*. A suite of other factors are known to affect farmland bird populations and these preliminary analyses should be viewed only as indicative of an effect of area of set aside. They merit further investigation and more rigorous analyses, for example, to derive how extending the time series back to 1988 and/or considering birds in different taxonomic, or functional groups affects the direction and significance of correlations. However, the results do provide the first suggestion of a potential positive effect of set aside at the population level for widespread farmland birds. **The predicted loss of set aside in the near future could therefore have a significant negative impact on the population trends of several key farmland bird species and hence the Farmland Bird Index as a whole. There are several options within ELS designed to provide the winter food benefits of set-aside but few options would provide the equivalent foraging and nesting habitat in summer. Consideration should be given to options such as summer fallow to mitigate some of the potential negative impacts of the future loss of set-aside. The scheme design needs to be altered to encourage greater take up of in-field options if ELS is going to provide winter foraging habitat on the same scale as set-aside.**

6. The success with which ELS delivers the Farmland Bird PSA target will be largely determined by the extent of uptake of key options. However, few empirical studies have attempted to quantify the area of a given option required to have an effect at the population level. Under objective 5, we used a theoretical approach, with three stages, to attempt to address this issue. First, population models were used to determine: (i) the magnitude of change required in the key demographic rate (i.e. the factor limiting population growth) to result in a small (1%) annual population increase; (ii) how the magnitude of these parameters varied if only a proportion of the population is affected. The smaller the proportion of the population affected, the greater the increase in the demographic rate required. The lower limit to this proportion is set by the maximum possible value of the demographic parameter concerned. Assuming the ‘proportion of the population’ to be roughly equivalent to the ‘proportion of farmland’, this provides an estimate of the minimum area of farmland required under relevant options to effect a population increase. Next, each ELS option was scored according to whether they would definitely (good scientific evidence) or potentially (less evidence) deliver summer food, winter food or nest sites for each species. Using ELS uptake data for November 2006, the total area of farmland that had options affecting the key parameter for each species was then calculated. Finally, this information was combined to

ask (i) is current ELS uptake sufficient and, if not, (ii) will it be sufficient under the predicted future 70% uptake of ELS?

7. The procedure outlined in (6) was carried out for 12 species with an annual population growth rate of <1% (Kestrel *Falco tinnunclus*, Grey Partridge *Perdix perdix*, Lapwing, Turtle Dove *Streptopelia turtur*, Starling *Sturnus vulgaris*, Skylark, Yellow Wagtail, Tree Sparrow *Passer montanus*, Linnet, Yellowhammer *Emberiza citrinella*, Reed Bunting, Corn Bunting) and suggests mixed results. **For seven species – Lapwing, Turtle Dove, Skylark, Yellow Wagtail, Starling, Linnet and Yellowhammer, the current uptake of ELS options is insufficient to effect a population growth; for one, Grey Partridge it is close to sufficient; for two, Kestrel and Tree Sparrow, it is sufficient; and, for two, Reed Bunting and Corn Bunting, results are mixed** (The latter are limited by more than one demographic factor and uptake was insufficient or sufficient/approaching sufficient depending on the factor concerned).

8. **Under a predicted 70% uptake rate for ELS the area under relevant options would be insufficient for five species - Lapwing, Turtle Dove, Yellow Wagtail, Linnet and Yellowhammer,** but it is predicted to become sufficient or nearly sufficient for Grey Partridge, Skylark and Starling (with a mixed outcome for Corn Bunting and Reed Bunting).

9. Ranking species in terms of the likelihood of ELS achieving 1% growth suggested **Turtle Dove may be the species least likely to benefit from ELS options. Yellow Wagtail, Lapwing and Linnet were also predicted to be relatively poorly served by ELS.** For two species, Corn Bunting and Reed Bunting, there were two limiting factors and for each species ELS option uptake was sufficient or nearly sufficient for one but not for the other. **In general the shortfalls are caused by a lack of certainty about the extent to which grassland options deliver food and/or nest sites and low uptake of in-field options.**

10. There are a number of important caveats associated with this modelling procedure. For example, it may have ‘under estimated’ the effectiveness of ELS in several ways. First, ELS options were considered to have an effect on the key parameter only where such evidence existed in the literature. If potential effects, based on general ecological knowledge rather than published evidence, were also included, the proportion of farm area under a relevant ELS options increased substantially, although they were still insufficient for Corn Bunting and, to a lesser extent, Grey Partridge, Turtle Dove, Skylark, Yellow Wagtail, Starling. Second, the models assume only a single key parameter will be affected and other parameters stay constant, whereas it is likely that that management options that have a primary effect on the key parameter are also likely to affect other demographic parameters. Adjusting models slightly for this again resulted in more achievable targets for some species, but not for Lapwing, Turtle Dove, Yellow Wagtail, Skylark, Linnet, Yellowhammer and Corn Bunting. The effectiveness of ELS could also be over estimated by assuming that ELS options deliver increases in the limiting demographic rate up to the maximum rate. If this is not true (which seems likely at least in some cases) then the area of land required is greater than predicted here and fewer species targets may be achievable.

11. This novel approach to assessing how much habitat is required to deliver population recovery in relation to current and predicted uptake of ELS should be viewed as a guide. It may, therefore, be more informative to consider the broad patterns, rather than the results for each individual species. **The two key findings in this respect are: (i) the lack of certainty of delivery through grassland options – this reflects a lack of research which is to some extent already being addressed through a number of Defra-NE funded projects; and, (ii) the lack of uptake of in-field options and perhaps to a lesser extent, the more complex/demanding field margin and boundary options. Over and above these broad patterns, we consider four species, Turtle Dove, Yellow Wagtail, Lapwing and Linnet, to be poorly served by ELS.** Turtle Dove requires seed-rich foraging habitats in the breeding

season (e.g. conservation headlands) which have a poor uptake. Yellow Wagtail and Lapwing both require similar in-field nesting habitat options that are unpopular in terms of uptake. For Linnet however, poor forecast delivery by ELS is largely a result of the uncertainty of the value of grassland options.

12. Objective 6 was designed to explore the potential value of a new and novel risk assessment model in predicting the impact, on farmland birds, of policy reforms likely to cause land-use change. Two land-use change scenarios were explored: a) predicted declines in the area sown to (spring) barley and sugar beet in favour of winter wheat and oil seed rape, with increased block cropping of these simplified rotations and b) increased growth of biofuel crops on set-aside land. The risk assessment process has three stages. Forty-two of the species included in these analyses, including 16 of the 19 species in the farmland bird index, either forage and/or nest in the cropped area of arable fields and are susceptible to exposure to these changes. If either of these land-use changes occurred, three species, Meadow Pipit *Anthus pratensis*, Wood Pigeon *Columba palumbus* and Kestrel are predicted to be re-classified to a less favourable conservation status. If both an increase in block cropping and an increase in the growth of biofuel crops took place, seven species are predicted to be re-classified to a less favourable conservation status, with Meadow Pipit, Kestrel and Barn Owl *Tyto alba* all predicted to become red-listed. It should be highlighted that these predictions assume UK-wide land-use change and therefore exposure of the whole population of vulnerable species to these hazards.

13. Implications and recommendations for policy recommendations.
    - **the overall quantity of farmland entering the scheme is broadly on track and is not the main reason why the scheme should not be potentially successful**
    - **There is scope for improving the quality of some individual options, eg extending duration of options delivering seed food in winter and increasing structural heterogeneity of grass margin options**
    - **The biggest problem is the pattern of uptake, i.e. the mix of options chosen. The popularity of some and unpopularity of others results in gaps in the resource provision necessary to help certain species sufficiently. This is already evident and seems unlikely to improve with increased overall uptake. There is a need to find ways of ‘rebalancing’ option uptake. The most important options to ‘promote’ are in field options such as Skylark plots, conservation headlands and stubbles and the more ‘complex’ field edge options such as enhanced hedgerow management. The number of farms, and hence area of land required, with these options may be reduced by targeting them towards certain options in particular geographical areas or habitats. This is particularly true for species with more restricted distributions such as Turtle Dove and Yellow Wagtail.**
    - **The loss of set-aside is potentially a major risk factor to the PSA target and at present it is hard to see how ELS options, however well designed, could provide sufficient quantity and distribution of resource to replace it. This is particularly true for the summer fallow nesting and foraging habitat it provides, but stubble options may replace the winter food value of set aside. It should be noted that if the ELS options designed to ‘replace’ set-aside deliver high quality resources the area required is likely to be considerably less than that of set-aside.**

14. If several species are not well served by the ELS, it is almost certainly not succeeding in its underlying biodiversity objective to ‘improve the health of the whole ecosystem(s)’, In this context, it is important to stress that there are **several species that are (a) still declining and (b) unlikely to be helped sufficiently by the present pattern of uptake even at higher volume. The level of benefits depends on option quality, option quantity and delivery, but the option mix is probably the most important variable with the current uptake patterns. Overall, quantity seems to be on track in terms of numbers of farms entering**

the scheme and although there is some scope for improving the quality (i.e. effectiveness) of individual options, this is secondary compared to the overall imbalance in terms of options chosen. In particular it is vital to promote higher uptake of in-field and more complex margin/boundary options and to continue to enhance knowledge of delivery in grassland landscapes.

2. BACKGROUND AND INTRODUCTION

Between 2001 and 2002, BTO, RSPB, GCT and Oxford University conducted a short research project (BD1618 for MAFF and EN) to establish the state of current knowledge on the species included in the farmland bird index (FBI), identify the main gaps and to suggest what measures would be required to meet the recently adopted PSA target which aims to reverse the decline in farmland birds by 2020. That project was successful in identifying the main resource requirements of the FBI bird species, for a very few species the amounts of these resources needed for population recovery, and the ability of current agri-environment scheme packages to deliver these resources (Vickery *et al*. 2004). Uncertainties remained over the resources needed by some species (e.g. Yellow Wagtail), but primarily over the amount of resource needed to effect population recovery. Nevertheless, project BD1618 proved helpful in influencing the decision to deploy, and the design of, the ELS pilot scheme. Now that ELS has been rolled out nationally in England as part of ES in 2005, it was considered timely to again review what we know and to determine whether we can identify any potential shortcomings in the ability of ES (particularly ELS) to help deliver the PSA target, especially given the impending disappearance of compulsory set-aside. In particular, this work is needed to inform a ‘Review of Progress that will run from May 2007. The work required was identified through discussions with NE and Defra, and fell into seven distinct objectives; we report against each of the objectives below in turn. In most cases we provide summaries in the text below and full details in the relevant appendix numbered according to objective number.

Objective 1: To update the evidence base and identify remaining knowledge gaps of resource requirements and causes of decline of farmland birds.

Objective 2: To review knowledge on practical measures to improve the quality of ELS options.

Objective 3: To review knowledge on optimal ways to deploy options in the landscape.

Objective 4: To review knowledge for past value of set-aside for farmland birds and the potential impact of its loss.

Objective 5: To assess the proportion of landscape required under specific management to produce a population increase in relation to current availability under ELS.

Objective 6: To predict likely future trends in the farmland bird index.

Objective 7: To make recommendations for future research and the design and operational delivery of ES.

3. OBJECTIVE 1: TO UPDATE THE EVIDENCE BASE AND IDENTIFY REMAINING KNOWLEDGE GAPS OF RESOURCE REQUIREMENTS AND CAUSES OF DECLINE OF FARMLAND BIRDS

See Appendix 1 for full text and all references for "species specific and generic resources" (pages 45-92). See Appendix 2 for full text and all references for effects of "ELS options on farmland birds" (pages 93-136).

The purpose of Objective 1 was to update the literature review of species-specific and generic resource requirements conducted during the initial PSA review (BD1618) with current research published since 2001. Comprehensive literature searches of relevant databases (e.g. Web of Science and Zoological Record) identified a wealth of farmland bird literature published post-2001, of which the findings of 60 new references (plus 13 references published pre-2001) were of direct relevance (see Appendix 1). The extent to which individual species accounts were updated with new information varied; five were altered significantly: Lapwing, Skylark, Yellow Wagtail, Reed Bunting, Corn Bunting; seven moderately: Kestrel, Grey Partridge, Barn Owl, Rook, Starling, Tree Sparrow, Yellowhammer; and seven were essentially unaltered: Stock Dove, Wood Pigeon, Turtle Dove, Whitethroat, Jackdaw, Linnet, Greenfinch. A summary of the updated resource requirements of FBI species is presented in Tables 1.1 and 1.2.

For the majority of the Farmland Bird Index species, the new research simply reinforced what was previously understood about the ecology of these birds, but simply adding a greater degree of detail. For one species, however – the Yellow Wagtail – recent research (Gilroy 2006) has contributed to a far greater understanding of its ecological requirements in arable farmland. For example, Gilroy (2006) demonstrated a mid-season shift in the habitat associations of Yellow Wagtails in a population in East Anglia, with breeding territories being most closely associated with autumn-sown crops in early May, but an increasing preference for potatoes with the progression of summer. This shift was interpreted as autumn-sown crops becoming less favourable as their increasing sward height and density limited ground access (Gilroy 2006). Gilroy (2006) speculated that because autumn-sown crops dominate much of the arable landscape in Britain and Europe, a lack of suitable breeding habitat in late summer may curtail the breeding season of Yellow Wagtails, as is the case as for Skylarks.

Gilroy (2006) also showed that nest predation rates of Yellow Wagtail varied according to crop type and nest placement within the crop. The likelihood of predation correlated with proximity to the nearest field edge, with more predation occurring at distances within 60 m from the boundary, than further away from the margin (Gilroy 2006). Correspondingly, Yellow Wagtails showed a strong avoidance of areas within 60 m of the field edge for nesting, while strongly preferring distances exceeding 100 m in both wheat and potato crops. Additionally, in autumn-sown wheat, the probability of predation was greater closer to tramlines than further away. This can be explained by the fact that predators frequently forage along tramlines, and nests in greater proximity to the edge are more likely to be detected (Gilroy 2006). However, Yellow Wagtails, as with Skylarks, frequently place nests very close to tramlines - as these provide the only ground-access points within the otherwise dense and uniform crop. Hence, crop structure restricts birds to nest in areas where predation risk is high. Nests in field bean crops experienced particularly high predation rates, compared to other crop types (Gilroy 2006). As bean crops gain height, abscission of the lower leaves results in an increase in horizontal visibility at ground level, which will facilitate detection by predators (Gilroy 2006). In contrast, visibility decreased with height in other crop types. The result is that beans seem to represent an ecological trap for this species.

Studies of the ecology of farmland birds have largely been biased towards arable landscapes, but there have been considerable recent advances in our understanding of the needs of birds in grassland habitats. This research has highlighted the intricate interaction between food abundance and food availability within grassland biotopes. Research has shown that tall grass swards are often characterised by an abundance of invertebrates, but it is also know that many species of farmland bird prefer to forage in short grass swards, because of a combination of enhanced prey and predator detectability and improved mobility (Devereux *et al*. 2004; Butler and Gillings 2004). This work implies therefore that a mosaic of different sward heights within agricultural grasslands would afford the greatest foraging opportunities for farmland birds. The principal questions remaining to be resolved are how to best deliver this sward heterogeneity through agri-environment options, and at what spatial scale such prescriptions would need to be implemented to see a measurable effect on farmland bird populations. Furthermore, another insight that has emerged with recent research is the need to provide seed resources for granivorous birds in grassland systems (Robinson *et al*. 2001). Measures exist under the ELS scheme to encourage the inclusion of seed-bearing crops in grassland (e.g. wild bird crops, brassica fodder crops, whole crop silage), while other prescriptions are currently being developed (leaving final cut silage *in situ* overwinter, Buckingham and Peach 2006).

Table 1.1. Main nesting, foraging habitat and food requirements of the species in the Farmland Bird Index during the breeding season. Black squares indicate resources considered to be of major importance; grey squares those of secondary importance or for which selection was not consistent. 4 = important resource, documented in published study. 3 = important resource, expert opinion. 2 = secondary resource, documented in published study. 1 = secondary resource, expert opinion.
* in some areas (e.g. NE Scotland), grassland is an important nesting and foraging habitat for corn bunting

		Kestrel	Grey Partridge	Lapwing	Stock Dove	Woodpigeon	Turtle Dove	Barn Owl	Skylark	Yellow Wagtail	Whitethroat	Jackdaw	Rook	Starling	Tree Sparrow	Linnet	Goldfinch	Greenfinch	Reed Bunting	Yellowhammer	Corn Bunting*
Nesting requirement	Buildings	2			2			4				2		4	2						
	Tree holes	4			4			4				4		4	4						
	Trees	▨				4	2						4		2		4	4			
	Shrubs					2	4				2					2	4	4	2	2	
	Hedges					2	4				4				1	4	2	2	2	4	
	Margins/rank grass and herbs		4	2						2	4								4	4	4
	Cereal crops		2	4					4	4											4
	Broad-leaved crops			4					2	4									4		2
	Grassland		2	4					4	4											2
Foraging habitat	Woodland				1	1															
	Scrubland				1	1					3				3			1	2	1	
	Parks/gardens				1	1						1		2	2			1			
	Hedges										3				3			1	2		
	Margins/rank grass	3	2		1		2	4	2	2	3	2		2	1	2	1	1	2	4	4
	Damp/aquatic habitats			4				2		4					4				4	1	1
	Cereal		4	2	2	2	1		4	2			1		1	2			2	4	4
	Broad-leaved crops			2	3	4	4		2	2			1		1	4			4	2	1
	Set-aside: rotational	1	4	2	1	4	1	1	3	1		1	1	1	1	3	3	1	2	2	1
	Set-aside: non-rotational	3	4	1	1	4	1	3	4	1		1	1	1	1	3	3	1	1	2	4
	Grassland	2	2	4				2	2	2		4	4	4		2	2				2
Food	Tree seeds/fruit					2					2	2						2			
	Grain				4	4	4					2	2		2			2		2	2
	Weed seeds		2		4	4	4								2	4	4	4		2	
	Rape				2	2	2									4		4	2		
	Foliage		2		2																
	Soil invertebrates	2	2	4	2	2	2		2			2	4	4	2						
	Other invertebrates	2	4	2	2	2	2		4	4	4	4	2	2	4		2	2	4	4	4
	Vertebrates	4						4				2	2								

Table 1.2. Main foraging habitat and food requirements of the species in the Farmland Bird Index during the non-breeding season. Black squares indicate resources considered to be of major importance; grey squares those of secondary importance or for which selection was not consistent. 4 = important resource, documented in published study. 3 = important resource, expert opinion. 2 = secondary resource, documented in published study. 1 = secondary resource, expert opinion.

		Kestrel	**Grey Partridge**	**Lapwing**	**Stock Dove**	**Woodpigeon**	**Barn Owl**	**Skylark**	**Jackdaw**	**Rook**	**Starling**	**Tree Sparrow**	**Linnet**	**Goldfinch**	**Greenfinch**	**Reed Bunting**	**Yellowhammer**	**Corn Bunting**
Foraging habitat	Woodland														1			
	Scrubland														1			
	Parks/gardens											1			3	1		
	Hedges		1									1			1	1		
	Margins/rank grass	3	1		1		4	1	1			1	1	1	1	1	1	1
	Damp/aquatic habitats						2									1		
	Cereal			4	2	2		2	2	2	1							2
	Broad-leaved crops		2	2	1	3		2	2	2	1	3				1		2
	Set-aside: rotational	1	2		1	4	2	4	4		1	2	4	1	1	1	4	
	Set-aside: non-rotational	3	4		1	1	3	4			1		4	4	1	1	4	
	Stubble (non-set-aside or unspecified)		4	2	1	4		4			1	2	4	4	1	1	4	2
	Grassland	3	2	4			2		2	2	4							2
Food	Tree seeds/fruit					2			2	2	2			4	2			
	Grain		4		4	4		2	4	4	4	4			2	2	4	4
	Weed seeds		4		2	4		4	2	2	2	4	4	4	4	4	2	2
	Rape				4	2						2						
	Foliage		2		2	2		2										
	Soil invertebrates	2		4				2	2	4	4							
	Other invertebrates	2		2				2	2	2	2					2	2	2
	Vertebrates	4					4		2	2								

4. OBJECTIVE 2A AND 2B: TO REVIEW KNOWLEDGE ON PRACTICAL MEASURES TO IMPROVE QUALITY OF CURRENT OPTIONS.

This section of the review had two primary objectives. Firstly, to review the evidence that agri-environment options in Entry Level Stewardship (ELS) scheme deliver measurable benefits for farmland birds. Secondly, to identify possible modifications to existing prescriptions that may improve their delivery. We will review the principal findings of these two objectives separately in the following summary.

OBJECTIVE 2A – REVIEW OF THE EFFECTS OF ENTRY LEVEL STEWARDSHIP AGRI-ENVIRONMENT OPTIONS ON FARMLAND BIRDS.

REVIEW OF EVIDENCE FOR DELIVERY OF ELS OPTIONS

Table 2a.1. A summary of the extent of evidence that ELS options provide important nesting and feeding opportunities for farmland birds during summer and winter. **% potential delivery:** percentage score of delivery for option based on suite of 13 farmland birds (Kestrel, Grey partridge, Lapwing, Turtle Dove, Barn Owl, Skylark, Yellow Wagtail, Starling, Tree Sparrow, Linnet, Yellowhammer, Reed Bunting and Corn Bunting) – 100% would equal 'good' delivery for all 13 species. **No. species:** count of species for which option delivers (or is expected to deliver) some benefit. **Delivery:** Good = evidence or strong expectation of benefit of that option for one or more species; Some = option may have some limited benefits for one or more species if managed in specific way (From R Winspear review from NE).

Option	nesting			summer food			winter food		
	% potential delivery	no. species	Delivery	% potential delivery	no. species	Delivery	% potential delivery	no. species	Delivery
EB1 - Hedgerow management (on both sides of hedge)	15	2	Good	15	2	Good	0	0	None
EB2 - Hedgerow management (on one side of hedge)	15	2	Good	15	2	Good	0	0	None
EB3 - Enhanced hedgerow management	35	7	Good	15	2	Good	0	0	None
EB8 - Combined hedge and ditch management (incorporating EB1)	15	2	Good	15	2	Good	0	0	None
EB9 - Combined hedge and ditch management (incorporating EB2)	15	2	Good	15	2	Good	0	0	None
EC1 - Protection of in-field trees (arable)	31	4	Good	0	0	None	0	0	None
EC2 - Protection of in-field trees (grassland)	31	4	Good	0	0	None	0	0	None
EE1 - 2m buffer strips on cultivated land	15	3	Good	65	10	Good	18	2	Good
EE2 - 4m buffer strips on cultivated land	15	3	Good	65	10	Good	18	2	Good
EE3 - 6m buffer strips on cultivated land	19	4	Good	65	10	Good	18	2	Good
EE4 - 2m buffer strips on intensive grassland	4	1	Some	35	5	Good	18	2	Good
EE5 - 4m buffer strips on intensive grassland	4	1	Some	35	5	Good	18	2	Good

EE6 - 6m buffer strips on intensive grassland	4	1	Some	35	5	Good	18	2	Good
EE7 - Buffering in-field ponds in improved grassland	8	1	Good	31	4	Good	18	2	Good
EE8 - Buffering in-field ponds in arable land	8	1	Good	54	7	Good	18	2	Good
EF1 - Field corner management	27	6	Good	65	10	Good	18	2	Good
EF2 - Wild bird seed mixture	12	2	Good	54	9	Good	59	7	Good
EF3 - Wild bird seed mixture on set-aside land	12	2	Good	54	9	Good	59	7	Good
EF4 - Pollen & Nectar flower mix	0	0	None	50	8	Good	0	0	None
EF5 - Pollen & Nectar flower mix on set-aside land	0	0	None	50	8	Good	0	0	None
EF6 - Over-wintered stubbles	15	3	Good	15	2	Good	73	8	Good
EF7 - Beetle banks	23	4	Good	58	8	Good	18	2	Good
EF8 - Skylark plots	12	2	Good	15	2	Good	0	0	None
EF9 - Conservation headlands	0	0	None	73	10	Good	0	0	None
EF10 - Unfertilised conservation headlands in cereal fields	4	1	Some	73	10	Good	0	0	None
EF11 - 6m uncropped culivated margins (in arable)	0	0	None	73	10	Good	59	7	Good
EG1 - Under sown spring cereals	19	3	Good	69	9	Good	0	0	None
EG2 - Wild bird seed mixture in grassland areas	4	1	Some	65	9	Good	59	7	Good
EG3 - Cereals for whole crop silage then stubbles	0	0	None	54	7	Good	0	0	None
EG4 - Cereals for whole crop silage followed by over-wintered stubbles	19	3	Good	54	7	Good	64	7	Good
EK1 - Take field corners out of management	12	3	Some	46	6	Good	18	2	Good
EK2 - Permanent grassland with low inputs	4	1	Some	65	10	Good	55	10	Good
EK3 - Permanent grassland with very low inputs	15	3	Good	69	11	Good	55	10	Good
EK4 - Management of rush pastures (outside of LFA)	12	2	Good	4	1	Some	5	1	Some
EK5 - Mixed stocking	0	0	None	0	0	None	0	0	None
EL1 - Field corner management (LFA land)	8	2	Some	31	4	Good	18	2	Good
EL2 - Manage permanent in-bye grassland with low inputs	4	1	Some	50	8	Good	45	9	Good
EL3 - Manage in-bye pasture and meadows with very low inputs	15	3	Good	54	9	Good	45	9	Good
EL4 - Management of rush pastures (LFA land)	12	2	Good	4	1	Some	0	0	None

A review of the options (see Appendix 2a) shows strong evidence that some of the agri-environment options prescribed under ELS deliver measurable benefits for farmland birds (Table 2a.1). These benefits are in the form of nesting (e.g. ditch and hedgerow management) and foraging (e.g. grass field margins) opportunities during the breeding season, and also foraging opportunities during the winter period (e.g. over-wintered stubbles and wild bird crops). However, it should be noted that there is a considerable bias in the manner in which research on prescription efficacy has been targeted at different suites of options (see above table). The effects of the provision of field margin and arable ELS options on farmland birds have received significant research attention, but many other groups, including options for boundary features, trees and woodland, lowland grassland, and the uplands, have been less thoroughly researched. One suite of prescriptions, in particular, for which relatively little is known about their benefits is the lowland grassland options. Whilst we can predict that many options (e.g. low inputs) will be of benefit the scientific evidence base to support this is rather weak. Losses of biodiversity from lowland grassland are often equivalent to or exceed those of arable dominated regions (Chamberlain and Fuller 2001), and the evaluation (and adjustment of) agri-environment schemes for these habitats is a key objective. Some recent research has begun to assess the potential merits of the lowland grassland prescriptions (e.g. Evans *et al.* 2007, Defra 2007), but much more needs to be done to address this knowledge gap. In addition, there also appears to be a slight bias in the evaluation of prescription benefits in different seasons (i.e. more in summer than winter), only part of which is attributable to the particular seasons to which individual options have been targeted.

OBJECTIVE 2B - REVIEW OF PRACTICAL MEASURES TO IMPROVE THE DELIVERY OF ELS OPTIONS

Table 2b.1 summarises the major recommendations advanced to improve the delivery of ELS options. In the following text, we comment on some of the these key recommendations.

For agri-environment schemes to be able to effectively counter the broad scale declines of farmland birds in Britain, they must fill critical resource gaps for target species (Siriwardena *et al.* in press). A review of scientific literature was undertaken to assess whether and how current options could be modified to enhance their ‘quality’ for birds (see Appendix 2b). In the text below we highlight the two most important changes to arise from this review, namely; (i) extension of the period of stubble retention later into winter (ii) management of grass margins to increase structural heterogeneity (particularly opening up the sward to improve accessibility of prey).

However, this review has highlighted that the provision of two key suites of ELS prescriptions, the over-wintered stubble options (EF6, EG4, EG5) and wild bird crop options (EF2, EF3, EG2), may not adequately correspond with the period of greatest resource requirement. Specifically, it is the prevailing view that winter food resources for granivorous species are at their most depleted during late winter and early spring (mid Feb. to end of Mar.; Evans *et al.* 2004; Siriwardena and Anderson 2007; Siriwardena *et al.* in press), but existing over-wintered stubble prescriptions permit the ploughing of stubble fields from the 15th February onwards, while wild bird crop options do not specify a date before which they cannot be harvested. Thus, these options permit a potentially very valuable food supply to be removed prior to the period during which it is most needed. It is not our contention that over-wintered stubble prescriptions in their current form have been completely ineffective in combating farmland bird declines – indeed, there is good evidence to the contrary (Gillings *et al.* 2005) – but such an alteration to these prescriptions would yield maximal benefits for granivorous birds. It is the recommendation of this review, therefore, that consideration be given to the possibility of extending the period of obligatory stubble retention until at least the 15th March. It may be necessary to also consider the potential impact on uptake as such an extension may impact on the establishment of the following crop.

Table 2b.1. Summary of major recommendations to improve the delivery of ELS options. No significant recommendations were made for the following options: EB3, EB8, EB9, EC1, EC2, EE7, EE8, EF4, EF5, EF7, EF9, EF10, EF11, EG2, EK4, EK5, EL4. For some options, multiple recommendations were put forward, but only those regarded as having the greatest potential impact are listed here.

Option	Code	Major recommendations	Benefits
Hedgerow management (on both sides of hedge)	EB1	Extend no cutting period to 31st August	No disturbance of nests initiated in August
Hedgerow management (on one side of hedge)	EB2	Extend no cutting period to 31st August	No disturbance of nests initiated in August
2 m, 4 m and 6 m buffer strips on cultivated land and on intensive grassland	EE1 – EE6	Use graminicides or scarify margins to open sward	Enables greater access to food for foraging birds
Field corner management	EF1	Prevent mowing between 1st March-31st August	Prevents destruction of nests of ground-nesting birds
Wild bird seed mixture	EF2	Introduce restrictions on cutting date of WBCs	Ensures provision of food extends into late winter
Wild bird seed mixture on set-aside land	EF3	Allow cultivation of WBCs in single-species strips	Improves changes of successful establishment and management.
Over-wintered stubbles	EF6	Extend retention of stubbles into mid-March	Ensures provision of food extends into late winter
Skylark Plots	EF8	Position aw ay from field buffer strips	Reduce nest predation
Undersown spring cereals	EG1	Extend retention of stubbles into mid-March	Ensures provision of food extends into late winter
Wild bird seed mixture in grassland areas	EG2	Introduce restrictions on cutting date of WBCs	Ensures provision of food extends into late winter
Cereals for whole crop silage followed by over-wintered stubbles	EG3	Extend retention of stubbles into mid-March	Ensures provision of food extends into late winter
Brassica fodder crops followed by over-wintered stubbles	EG4	Extend retention of stubbles into mid-March	Ensures provision of food extends into late winter
Take field corners out of management	EK1	Prevent mowing between 1st March-31st August	Prevents destruction of nests of ground-nesting birds
Permanent grassland with low and very low inputs	EK2 – EK3	Introduce grazing restrictions	Creation of heterogeneous sward, increasing foraging opportunities for birds
Field corner management (LFA land)	EL1	Prevent mowing between 1st March-31st August	Prevents destruction of nests of ground-nesting birds
Manage permanent in-bye pasture with low and very low inputs	EL2 – EL3	Introduce grazing restrictions	Creation of heterogeneous sward, increasing foraging opportunities for birds

Recently, experimental management options have been developed from studies of foraging habitat selection, which have demonstrated that it is not only food abundance that dictates patterns of habitat use, but food accessibility and perceived predation risk are also incorporated into behavioural decisions. These techniques have therefore focussed upon manipulating the vegetation height (e.g. mowing and topping) and sward density (e.g. scarification and selective graminicides) of agri-environment habitat features to either facilitate greater access to prey resources or to better suit the particular prey avoidance strategies of different species (Butler *et al*. 2005; Whittingham *et al*. 2006; Collins *et al*. 2007). To date, the preliminary results of these experimental management techniques appear relatively promising, with birds showing positive responses in many cases. For example, in the SAFFIE study, field margin management treatment was a significant predictor of the extent of bird usage, with bird densities being particularly high on the scarified and graminicide-treated boundaries (Henderson *et al*. 2007). In addition, the proportionate use of field margins in this study increased significantly over time, reflecting that managed margins became progressively more suitable for farmland birds as they matured (Henderson *et al*. 2007). Therefore, given these encouraging findings, and conditional upon similar positive benefits being demonstrated by further efficacy studies, it is the suggestion of this review that consideration should be afforded to their possible inclusion in relevant ELS prescriptions. However, it should also be noted that some of these experimental techniques require a considerable increase in the time and efforts devoted by farmers, and to act as an incentive in their uptake, point allocations will need to be revised accordingly.

Finally, an important caveat to note is that this review has focussed only on how existing agri-enviroment measures might be altered to improve their delivery of food and nesting resources for farmland birds. We do not, however, consider the agronomic costs or benefits of these proposed modifications. Clearly, such considerations are important, but whether the modifications are practically or politically feasible is beyond the scope of the current review. It is possible that some suggested modifications might reduce overall uptake (as has been highlighted for stubbles and wild bird cover options above). For example, stocking restrictions on the low input grassland options would reduce sward utilisation and possibly also the agricultural quality of the sward and may therefore reduce uptake of a currently popular option.

5. OBJECTIVE 3: TO REVIEW KNOWLEDGE ON OPTIMAL WAYS TO DEPLOY OPTIONS IN THE LANDSCAPE

See Appendix 3 for full text and all references (pages 137-146).

How AES can be optimized in terms of biodiversity value is a key question in conservation policy in the UK (Sutherland *et al.* 2006) and elsewhere in Europe. A great deal of evidence exists for the quality of various farm management techniques in relation to AES options (Appendix 2a). In previous reviews, Aebischer *et al.* (2003) and Vickery *et al.* (2004) identified few 'resource gaps' in terms of the foraging and nesting requirements provided for birds within existing schemes, and the current report reinforces this (Appendix 1 and 5). However, important knowledge gaps remain in relation to scale, specifically: the quality of the resource created, the quantity of that resource and the way in which it is deployed i.e. targeting and distribution at the national and local scale, configuration (size and shape of options) and local and landscape effects (e.g. interactions with landscape features/types and other options).

For AES to be cost effective, in terms of delivery, knowledge is needed not only of the quality of the prescription itself (i.e. resources provided and their availability), but also of how that prescription should be introduced into the landscape. In this review we consider three questions in turn:

(i) Scale: How much of the option is needed?
(ii) Configuration: How should the option be introduced at a field scale (e.g. strip or blocks; one large patch or several smaller patches of the same area; how far apart?
(iii) Context: Where should the option be introduced into the landscape to have maximum effect?

This section reviews the existing theoretical and applied literature relating to each issue, highlights any practical recommendations that can be drawn from this information and identifies important research questions that need to be addressed to maximise the effectiveness of AES in general and some options in particular. For each of these three key areas we consider literature relating to prey species for birds (invertebrates and, to perhaps a lesser extent plants) and birds themselves. Full details are given in Appendix 3 and summarised in the text below.

SCALE

Island biogeography theory predicts that island size has a profound effect on species richness (MacArthur and Wilson 1967), however, with the exception of Donald and Evans (2006), island biogeography has rarely been applied to the situation of high quality (agricultural) habitat patches within farmland. There is an extensive literature on small woodlands within agricultural landscapes (e.g. Hinsley *et al.* 1995, Opdam *et al.* 1995, Bellamy *et al.* 1996), suggesting woodland patches behave like islands for many bird species (and especially poor dispersers) in that local extinction rates are influenced by woodland size and to some extent isolation (being higher in small and/or isolated woodlands).

Research on the scale of habitat required (quantity or size of patches) is sparse and rather fragmented. A couple of studies on field margin size suggests that Barn Owls may benefit from 2 m rather than 6 m margins (Askew *et al.* 2007) and mortality of Corncrake chicks may be reduced by up to 80% by leaving an unmown margin of 9 m (Tyler *et al.*1998). Other than this, little is know about the relative value of margin width beyond the obvious that hedgerow avoiding species prefer wider margin widths (Vickery *et al.* in prep). At a larger scale, Gillings *et al.* (2004) considered the responses of breeding farmland bird populations sampled with 1-km^2 grids to variations in winter cropping area. This study suggested that, for Skylark, an average minimum of 10 ha of stubble per 1-km^2 was needed to stem the population decline.

In terms of the spatial distribution of resources, the degree of isolation of small woodland patches in agricultural landscapes does influence the probability of occurrence of a small number of woodland specialists (Nuthatch, Marsh Tit, Long-tailed Tit; Hinsley *et al.* 1995, Opdam *et al.* 1995) but there has been little research in this respect for birds of open farmland. The most comprehensive and detailed work is that of Siriwardena *et al.* (2006), who considered how the large-scale distribution (between 100 m and 10 km) of food patches in the arable landscape affected their use by birds in winter. They concluded that creating resource patches more than 1 km apart would be the most cost-effective to maximise winter bird use. It is, however, also important to note that it is likely that the spatial scale at which resources are deployed, say within AESs, will differ between the breeding and non-breeding season. Breeding birds tend to be more constrained in their dispersal, acting as central place foragers with respect to their hedge or field nest sites. Thus whilst patches of food can be deployed at considerable distances apart in winter (Siriwardena *et al.* 2006) they may be required in scattered patches at a much finer scale in summer. Indeed, most studies of the foraging ecology of farmland birds such as Yellowhammer and Corn Bunting suggest birds utilise food resources within ca 300 m of the nest, although some species, such as Linnet, forage over greater distances.

CONFIGURATION

There has been some research comparing biodiversity between margins and whole fields (Thies and Tscharntke 1999, Tscharntke and Kreuss 1999, Denys and Tscharntke 2002), but little work on the shape of options *per se*. This may be important because edge:area ratios will vary according to patch shape and therefore certain configurations may be subject to greater edge effects than others. For ground nesting farmland birds, edge effects may be key in determining predation rates with predation rates usually being higher at habitat edges (Major and Kendal 1996). However, most studies were, however, carried out in forested habitats and studies in open habitats have found vegetation structure of a patch, rather than the size, fragmentation extent or distance from edge, to be a key determinant of nest predation rate (e.g. Baines 1990, Howard *et al*. 2001, Wilson *et al*. 2001, Donald 2004).

CONTEXT

The context in which resources are provided, both at the local and the landscape scale, can be extremely important in determining the extent to which they are used by birds. At the local scale, for example, Skylarks prefer open landscapes and avoid nesting in smaller fields in close proximity to vertical features such as tree lines and hedgerows (Wilson *et al.* 1997). Lapwings prefer to nest in spring cereals that are adjacent to grass fields (Wilson et al. 2001). Siriwardena and Stevens (2004) found that use of artificial food patches by birds was influenced by local (and landscape) habitat variables. A major influence on the value of a margin for birds and their food resources is proximity to a good quality hedgerow, i.e. one that is well established, relatively species-rich and well managed (Vickery *et al.* in prep.), particularly in summer when many species nest in or at the base of hedgerows and forage nearby. In winter, proximity to hedgerows may be less important but they provide cover from predators (e.g. Evans 2004) and margins near hedgerows may still be favoured by foraging birds (e.g. Henderson *et al*. 2004).

Predation pressure is also likely to be a key factor with respect to the local context of AES option placement. The creation of Skylark plots, for example, close to those margins (<70-80 m) seems to result in high failure rates due to predation probably because the margin enhances predator numbers and encourages those predators into the crop (www.SAFFIE.com). Preferences for foraging in field centres or margins are often related to the species' predator avoidance strategy. Most farmland birds tend to fly to cover and this may result in food patches close to cover being more highly exploited (Siriwardena and Stevens 2004). It is important to note that creation of a high quality habitat that attracts large numbers of birds may act as a 'honey pot' for predators, particularly if the surrounding habitat is of poor quality (e.g. Tyler *et al*. 1998)

6. OBJECTIVE 4: TO REVIEW KNOWLEDGE FOR PAST VALUE OF SET-ASIDE FOR FARMLAND BIRDS AND POTENTIAL IMPACT OF ITS LOSS

See Appendix 4 for full text and all references (pages 147-151).

Removing land (i.e. set-aside land) from agricultural production was an initiative introduced in 1988 by the European Commission, as part of the Common Agricultural Policy (CAP), to reduce agricultural surpluses (Firbank *et al*. 2003). Initially, this scheme operated voluntarily, but following CAP reforms in 1992, eligibility for agricultural subsidies required that a proportion of arable land should be set-aside each year (Firbank *et al*. 2003). Since 1994, the amount of set-aside in the English agricultural landscape has fluctuated in line with both annual changes in the predetermined rates required of farmers wishing to receive Arable Area Payments and in the amount of voluntary fallow land left by farmers as part of their normal agricultural operations. Over this period the set-aside area has fluctuated between c. 250,000 and c. 575,000 ha, but on average, has constituted approximately 10% (c. 500,000 ha) of all arable land.

It is becoming increasingly clear that the introduction of set-aside in Britain, and more widely in Europe, has had beneficial repercussions for agricultural biodiversity. Studies of diverse taxa have suggested that species richness and population densities are often higher on set-aside than other types of land (reviewed in Buskirk and Willi 2004). The response of birds, in particular, to the provision of set-aside land has been well studied and recently reviewed (Roberts and Pullin 2007). Henderson *et al*. (2000) demonstrated that the relative abundance of birds during summer was higher on (rotational) set-aside than any other crop type for five of six functional groups of farmland birds (gamebirds, pigeons, Skylarks, thrushes and granivores). Furthermore, Buckingham *et al*. (1999) documented that five declining bird species (Grey Partridge, Linnet, Skylark, Yellowhammer and Cirl Bunting) preferentially selected fallow land (mainly set-aside) relative to other crop types during winter in Devon and East Anglia. The attractiveness of set-aside to farmland birds has generally been attributed to the enhanced foraging opportunities afforded by this habitat type (Henderson *et al*. 2000). It potentially provides a rich source of insects and weed seeds providing food in both summer and winter, the accessibility of which is enhanced by the patchy nature of the sward. It also provides nest sites for ground nesters such as Skylarks (Henderson *et al*. 2000).

Given the putative benefits offered by set-aside to farmland birds and that it has been a significant component of the agricultural landscape for over a decade, an obvious prediction is that it will have positively affected the population trends of some species. However, several authors have commented that the provision of set-aside has, in fact, had few measurable effects on the population trends of species exhibiting a close association with it (Fuller 2000; Henderson *et al*. 2000; Firbank *et al*. 2003). Nevertheless, it should be noted that these assessments have been based on a few species, using visual appraisals of the concordance between set-aside introduction and changes in bird populations. Here, we present an analysis of the effects of the provision of set-aside land on the population trends of the nineteen Farmland Bird Index (FBI) species. Our prediction is that variation in the availability of set-aside will be paralleled by fluctuations in the trends of some species.

METHODS

Data on bird population trends were derived from the BTO/JNCC/RSPB Breeding Bird Survey (BBS), a volunteer-based census that provides an index of annual changes in bird populations in Britain. We obtained national (i.e. all England) trend data for each of the 19 species included in the FBI and a composite trend describing the mean changes of all FBI species during the period 1994-2005 (the period of the BBS). Information on temporal changes in the availability of set-aside for this period was obtained from the Defra farming statistics online database[1].

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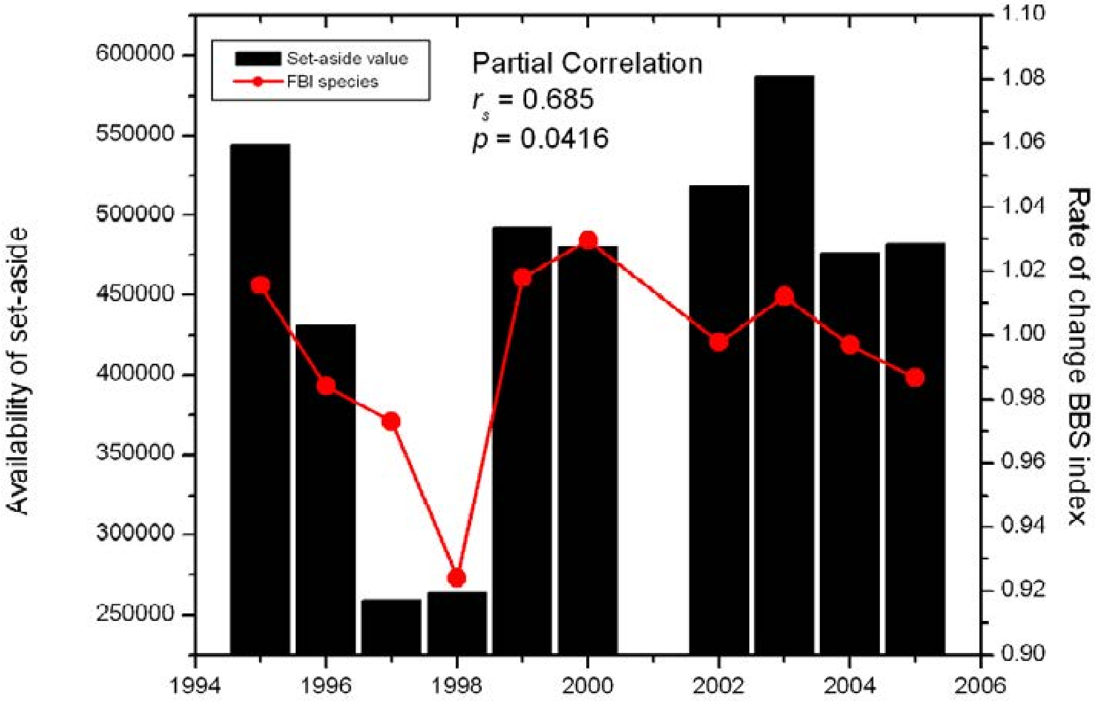
[1] http://www.defra.gov.uk/esg/work_htm/publications/cs/farmstats_web/default.htm

To evaluate whether changes in the availability of set-aside were associated with fluctuations in the population trends of individual species and the composite trend, we used Spearman's partial rank correlation analyses implemented in SAS v. 9.1. This method of analysis makes no distributional assumptions about the data, but allows possibly confounding factors to be accounted for. As trend indices in consecutive years are autocorrelated, between-year changes (index yr *n*/index yr (*n*-1)) in trend values were correlated with absolute values of set-aside (set-aside is not characterised by autocorrelation). We tested both for effects of the availability of set-aside in year *n* and in year (*n*-1) on bird population trends. Moreover, during exploratory rounds of data analysis, we noted that considerable declines in the composite trend of the FBI species coincided approximately with consecutive cold winters in 1996/97 and 1997/98. Therefore, mean winter temperature was incorporated in analyses as a partial variate to control for any fluctuation in population trends that was attributable to variation in winter climatic conditions. Finally, note that data from 2001 was disregarded from analyses, because the outbreak of Foot and Mouth disease amongst cattle in that year, and the subsequent restrictions regarding access to the countryside, meant that measures of bird population trends had to be interpolated from data in previous and subsequent years.

RESULTS

Figure 4.1. Temporal fluctuations in the rate of change of the composite BBS trend for all FBI species and in the availability of set-aside land. (2001 was removed from the analysis see text). Note that although the required rate between 1999 and 2005 remained constant at 10% there were notable annual fluctuations in the actual area due to additional voluntary set-aside/fallow land. No data are presented from 1994 as the rate of change in the BBS index relates to the change between 1994 and 1995.



The BBS population trend for all FBI species was significantly positively correlated with the availability of set-aside in year *n* (Fig. 4.1). Furthermore, the individual trends for two species, Lapwing and Linnet, were also significantly positively related with set-aside in year *n* (Table 4.1).

Of the 17 FBI species not characterised by a significant relationship (Table 4.1), 11 were positively associated, and six negatively associated with set-aside in year *n*; these disparate counts were not statistically significant (binomial test, $p = 0.3323$). In contrast, the individual-species and composite-species trends did not vary significantly with the availability of set-aside in the preceding year, although Grey Partridge did show a trend towards being positively influenced (Table 4.1).

Table 4.1. Partial correlation coefficients and *p*-values of correlations between FBI species and the availability of set-aside in year *n* and year (*n*-1).

	Set-aside in year n		**Set-aside in year (n-1)**	
Species	**Partial Correlation**	**p-value**	**Partial Correlation**	**p-value**
Corn Bunting	0.456	0.2174	0.095	0.8072
Goldfinch	0.56	0.1168	0.3	0.4332
Greenfinch	0.028	0.944	-0.114	0.7702
Jackdaw	0.505	0.1654	-0.237	0.5385
Kestrel	0.116	0.7661	-0.425	0.2544
Lapwing	***0.834***	***0.0052***	0.144	0.7121
Linnet	***0.791***	***0.0112***	0.439	0.237
Grey Partridge	-0.086	0.8247	0.621	0.0743
Reed Bunting	0.344	0.3645	-0.349	0.3579
Rook	-0.269	0.4837	-0.147	0.7063
Skylark	0.39	0.2998	0.364	0.3353
Stock Dove	-0.426	0.2531	0.381	0.3112
Starling	0.183	0.6369	-0.033	0.9329
Turtle Dove	-0.003	0.9935	-0.1	0.797
Tree Sparrow	0.218	0.5723	0.15	0.6993
Whitethroat	-0.137	0.7252	0.49	0.181
Wood Pigeon	-0.492	0.1787	-0.315	0.409
Yellowhammer	0.317	0.4056	-0.356	0.3467
Yellow Wagtail	0.379	0.314	0.575	0.1051
Mean Trend	***0.685***	***0.0416***	0.282	0.4622

DISCUSSION

A key finding from this analysis is that the composite trend for all FBI species varied according to the availability of set-aside, with more positive between-year population changes associated with an increased occurrence of set-aside. Perhaps the most persuasive demonstration of this correlation is the sharp decline in the BBS trend following a marked reduction in the amount of set-aside in 1997 and 1998 (Fig 4.1). This reduction occurred because the predetermined set-aside rates fell from 15% of arable land in 1996 to only 5% in 1997. Henderson *et al.* (2000) suggested that this represented: “one of the single largest changes in farming practice over two years”. The analysis here suggests this change may have been responsible, at least in part, for a further downturn in farmland bird populations.

In addition, the species-specific trends of Lapwing and Linnet were also positively associated with the availability of set-aside. Set-aside could benefit bird species both in winter and in the breeding season. Set-aside is known to be a favoured habitat for Linnet during winter (Buckingham *et al.* 1999), presumably because it offers an abundance of weed seeds; consequently, changes in its availability are likely to impact on over winter survival of this species. In contrast, although Lapwing preferentially select set-aside during the breeding season (Wilson *et al.* 2001), there is relatively little evidence implying that it is an important habitat in winter. Therefore, the route by which fluctuations in the amount of set-aside might influence the survival of Lapwing may well be improved productivity. Finally, it is noteworthy that although most are non-significant, the correlation coefficients for 8 granivorous passerines (corn bunting, goldfinch, greenfinch, linnet, reed bunting, skylark, tree sparrow and yellowhammer) in the above analyses are positive, which would be anticipated from existing knowledge of the use of set-aside by these species.

The results presented above suggest that changes in the availability of set-aside can influence the populations of some bird species. However, we advise some caution in interpreting and extrapolating these results. For example, although the composite trend was correlated with set aside availability there were few species-specific relationships. Only two farmland birds, from a total of 19 species, exhibited a significant correlation with the amount of set-aside, a number that could easily have arisen as a result of Type I error. The lack of significant correlations may be due to small sample sizes for some species, such as Corn Bunting and Tree Sparrow. More complex analyses could be used to investigate this further e.g. weight correlations by associated measures of precision to control for differences in estimate accuracy.

The relationship between land use change and bird populations is complex and set-aside is just one of many important factors. Previous work has highlighted the importance of factors such as weather (e.g. winter temperature) and land use intensity (measured through factors such as yield, levels of chemical inputs, extent of semi natural habitat) and cropping patterns (e.g. crop type and diversity). Furthermore, we have used the term set-aside to encompass a number of different habitats (permanent, rotational, industrial etc.) that differ widely in the habitat type and management and will provide very different resources for birds. For these reasons we stress that the correlation presented here should be viewed as an indicative of an effect rather than a robust relationship. These preliminary results require further rigorous analysis before weight is ascribed to the potential consequences of changes in the availability of set-aside on farmland bird populations. Future analyses to improve our understanding of the relationship between set-aside and bird population trends include: i) to extend the time series back to 1988 using data from the Common Birds Census (CBC); ii) to use the area of spring barley as a surrogate for the area of over-winter stubble created as part of the normal farming rotation and to see whether adding this to set-aside area improves the correlation, iii) as (ii) but extend the time-series back to 1970, iv) to explore how grouping the birds according to the different taxonomic, feeding etc. guilds affects the direction and significance of correlations.

Due to proposed reforms of the CAP by the European Union, it is very likely that set-aside will disappear from the farming landscape in 2009. Although these results should be viewed as 'preliminary' in many ways, they do suggest that without its substitution with an agricultural habitat with equivalent biodiversity benefits, this removal may precipitate a further reduction in the populations of European farmland birds. There are several options within ELS (and HLS) that potentially provide the winter food benefits of set-aside, e.g. stubble options (EF6, EG3 and EG4)and wild bird cover options (EF2, EF3 and EG2). However, these would cover a much smaller area that set-aside and as previous work has shown a great deal of stubble currently supports little seed food and hence few birds (see Gillings *et al*. 2006). If these options are to replace set-aside the stubble provided must be managed to be of high quality for birds. One option (in addition to that of having stubble preceded by low input crops) might be to leave a strip of the cereal crop unharvested (e.g. a conservation headland or mid field strip). With respect to the summer breeding and foraging opportunities offered by set aside, few options exist within the current suite that would provide the equivalent habitat and we suggest consideration should be given to options such as summer fallow. If this was left over the following winter it would also provide a high quality seed resource for birds. This may serve to mitigate some of the potential negative impacts of the loss of set-aside on biodiversity in general, and birds in particular.

7. OBJECTIVE 5: TO ASSESS THE PROPORTION OF LANDSCAPE REQUIRED UNDER SPECIFIC MANAGEMENT TO PRODUCE A POPULATION INCREASE IN DECLINING FARMLAND BIRD SPECIES AND COMPARE THIS WITH AVAILABILITY UNDER CURRENT UPTAKE OF ELS OPTIONS

See Appendix 5 for full text and references. (pages 153-182)

DEMOGRAPHIC RATES REQUIRED TO PRODUCE POPULATION GROWTH

AIMS

To determine the magnitude of change required in key demographic parameters to result in population increase of 1% over a period of one year[1], and to determine how the magnitude of these parameters varies if only a proportion of the population is subject to a change in those parameters.

METHODS

The methodology used in this section derives key information from Siriwardena and Vickery (2002)[2]. For brevity, we refer to this work as 'S&V' followed by the relevant table in that reference if used as a data source for the current analyses. The analyses were based on the calculation of inter-annual change based on demographic parameters, expressed by the following equation in S&V:

$$N_{t+1} = (N_t \times S_{AD}) + (N_t \times S_{FY} \times FPA \times S_{PF} \times NA \times 0.5) \qquad \text{eqn. 1}$$

where N_t and N_{t+1} is abundance in years t and t+1, S_{AD} is adult survival, S_{FY} is first-year survival, S_{PF} is post-fledging survival, FPA is fledglings produced per breeding attempt and NA is the number of breeding attempts per year. For some species, only juvenile survival S_{JV}, rather than S_{FY} and S_{PF}, was available from the literature. In these cases, S_{JV} replaced S_{FY} and S_{PF} in eqn. 1.

Demographic parameter estimates were derived for 18 Farmland Bird Indicator (FBI) species using data from S&V Table 3. Parameter estimates in this table were derived from the literature[3] and were subsequently adjusted in order to provide the best fit to the population trends. Estimates for a further FBI species, Grey Partridge, were taken from Aebischer (2002). S&V used CBC data only to derive population growth rate (PGR) for each species between 1990 and 2000. These estimates were updated using combined BBS and CBC data from 1990-2005 for England only. PGR was derived for each species using the log-linear Poisson regression approach of S&V. Parameter adjustment was carried out, following the methods of S&V. The updated demographic parameters and PGR for each species with PGR<1% over the period 1990-2005 are shown in Table 5.1.

For each species, S&V Table 5.4 identifies the key demographic parameter (and in some cases parameters) that is likely to be the main driver of population change. We used the parameters listed in S&V as the key parameters, but we also added an additional key parameter, FPA, for Reed Bunting as low productivity is likely to be inhibiting population recovery in this species.

We determined the demographic rate required to increase the population by 1% over one year, from a starting value of $N_t = 1$, by rearranging eqn. 1. Where the key parameter was identified as 'Survival' in S&V Table 4, we present results for only S_{FY} or S_{JV}, as much of the evidence suggests that juvenile rather than adult survival is likely to be the main driver of population change in several species.

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[1] Considered the minimum measurable change

[2] These represent the best available evidence to date, and it should be noted. The evidence is less good for some species (see S&V 2002 for full discussion)

[3] In: Aebisher, N.J., Bradbury, R., Eaton, M., Henderson, I.G., Siriwardena, G.M. & Vickery, J. (2003) *Predicting the Response of Farmland Birds to Agricultural Change.* BTO, Thetford

Table 5.1. Population growth rates (PGR) and adjusted demographic parameter estimates used to produce population models that predict future BBS/CBC trajectories continuing with the same trend as found for 1990-2005 in the absence of any demographic changes. Only species where PGR < 1.01 are considered.

Species	PGR	SAD	SFY	SJV	SPF	FPA	NA
Kestrel	0.999	0.548		0.257		3.50	1.00
Grey Partridge	0.955	0.415	0.415		0.300	8.60	1.00
Lapwing	1.006	0.655		0.430		1.63	1.00
Turtle Dove	0.941	0.590	0.400		0.850	1.30	1.60
Skylark	0.983	0.630		0.245		1.45	2.00
Yellow Wagtail	0.962	0.552	0.470		0.510	2.77	1.25
Starling	0.949	0.568	0.365		0.383	3.63	1.50
Tree Sparrow	1.007	0.405		0.305		3.03	1.30
Linnet	0.980	0.320	0.280		0.840	2.48	2.25
Yellowhammer	0.980	0.536	0.529		0.470	1.45	2.50
Reed Bunting	0.999	0.500	0.410		0.610	1.99	2.00
Corn Bunting	0.960	0.530	0.440		0.700	2.23	1.25

RESULTS

Demographic rate required for population increase

The key demographic rates required to achieve 1% population growth for each species with PGR<1.01 are given in Table 5.2. For a number of species, the increase required in the key parameter to produce population growth was small. For example, less than 10% increase is required for Kestrel, Lapwing, Skylark, Yellow Wagtail, Linnet, Yellowhammer and Reed Bunting. For others, the change would have to be larger, e.g. Grey Partridge, Turtle Dove and Corn Bunting each had at least one key parameter requiring an increase of > 10%.

Table 5.2. The key demographic rates required to achieve 1% population growth for FBI species. The baseline estimate is from Table 5.1.

Species	Key parameter	Rate required	Baseline estimate	% change required
Kestrel	FPA	3.600	3.50	3
	S_{JV}	0.264	0.257	3
Grey Partridge	FPA	9.558	8.60	11
Lapwing	FPA	1.651	1.63	1
Turtle Dove	NA	1.900	1.60	19
Skylark	NA	2.140	2.00	7
Yellow Wagtail*	NA	1.380	1.250	10
Starling	S_{FY}	0.424	0.365	16
Tree Sparrow	S_{JV}	0.307	0.305	1
Linnet	FPA	2.572	2.48	4
Yellowhammer	S_{FY}	0.556	0.529	5
Reed Bunting	FPA	2.04	1.99	2
	S_{FY}	0.420	0.410	2
Corn Bunting	NA	1.398	1.25	11
	S_{FY}	0.492	0.440	11

* Key parameter was listed as '?' in S&V Table 5.4. This value updated by J. Gilroy (pers. comm.).

Required rates for proportions of the population

The introduction of measures to improve demographic rates in farmland birds and therefore to increase populations, is likely only to be applied to a certain proportion of a population, whereas in Table 5.2, it is assumed that 100% of the population will change their key demographic rate (or, more realistically, that the population average will increase to the required rate). The next stage was therefore to see what the key demographic rate to achieve population growth would be for each species if only a proportion of the population increased that demographic rate (the remainder of the population is assumed to have the baseline demographic rates as presented in Table 5.2). We assume that ELS options are able to operate at maximum efficiency and cause a relatively high increase in key parameters. To this end, a literature search was carried out into the key parameters in each species in order to identify maximum values for each parameter. In all cases, mean values were used from a given study, rather than selecting maximum values of individual birds. These rates are shown in Table 5.3.

The question was then asked: what proportion of the population should reach the maximum key parameter in order to produce population growth? The calculation of this figure is shown in Fig. 5.1, taking Kestrel as an example. The lower dashed line shows the baseline rate of the key demographic parameter used in the current model (Table 5.2), the curve (derived from the modelling) shows the demographic parameter required to achieve population growth and the upper dotted line shows the maximum key demographic parameter from Table 5.3. If we assume that increasing the key demographic parameter above this maximum is not possible, then where this dotted line crosses the curve gives a measure of the minimum proportion of the population that would need to increase its key demographic parameter in order to affect overall population growth. In the example (Fig. 5.1), 25% of the population (as indicated by the shaded arrow) achieving the maximum key parameter would result in population increase. If less than 25% of the population were affected, population growth would not occur as it is assumed that the key parameter cannot be increased over its maximum value.

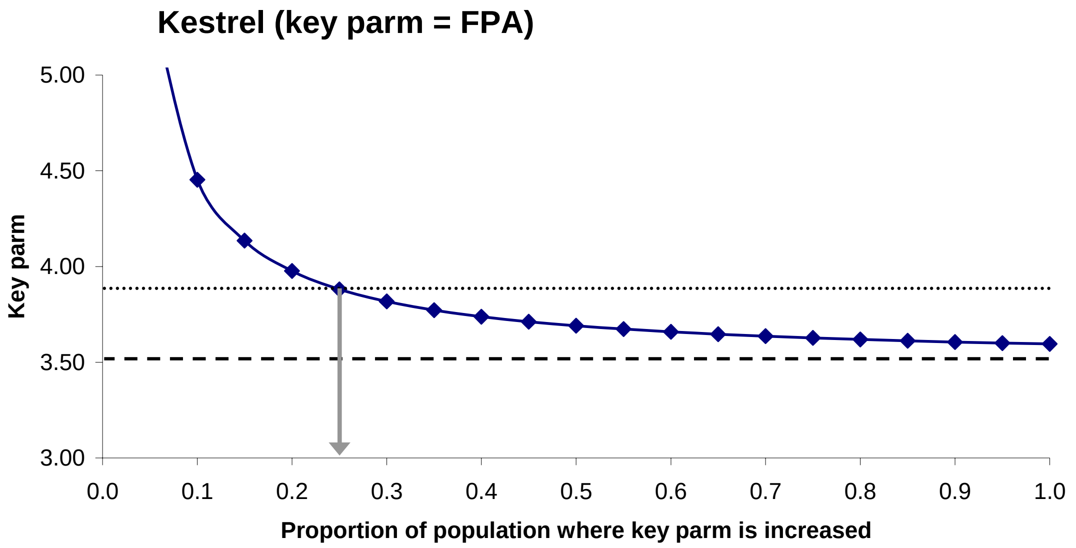
Table 5.3. Maximum key parameters used for each species with PGR<1.01 derived from the literature (the number of decimal places is given according to the source reference), the minimum proportion of the population that could result in population growth in the subsequent year if the maximum key parameter was reached, and the proportion of farmland covered by ELS options that will probably increase the key parameter. Each estimate is classified according to whether the proportion required represents an achievable target, where green = achievable, orange = possibly achievable and red = not achievable, given the parameter estimate required relative to the maximum.

Species	Key parameter	Maximum rate	Minimum proportion of population required	Current ELS area	ELS areas under 70% uptake
Kestrel	FPA	3.88	0.25	0.32	0.59
	S_{JV}	0.4	0.04	0.34	0.63
Grey Partridge	FPA	14.6	0.16	0.24	0.45
Lapwing	FPA	2.78	0.02	0.00	0.00
Turtle Dove	NA	2.9	0.22	0.01	0.03
Skylark	NA	2.74	0.18	0.10	0.19
Yellow Wagtail	NA	2	0.18	0.04	0.07
Starling	S_{FY}	0.614	0.26	0.23	0.44
Tree Sparrow	S_{JV}	0.40	<0.01	0.14	0.27
Linnet	FPA	2.98	0.18	0.01	0.02
Yellowhammer	S_{FY}	0.630	0.30	0.14	0.27
Reed Bunting	FPA	2.74	0.05	0.02	0.03
	S_{FY}	0.538	0.07	0.14	0.27
Corn Bunting	NA	3	0.09	0.14	0.28
	S_{FY}	0.538	0.53	0.15	0.27

The minimum proportion of the population that could result in population growth if the maximum key parameter was reached is shown for each declining species (and each separate key parameter if appropriate) in Table 5.3 (along with the proportion of area required to reach population growth when the maximum parameter is attained – see below).

ELS option area and key demographic rates

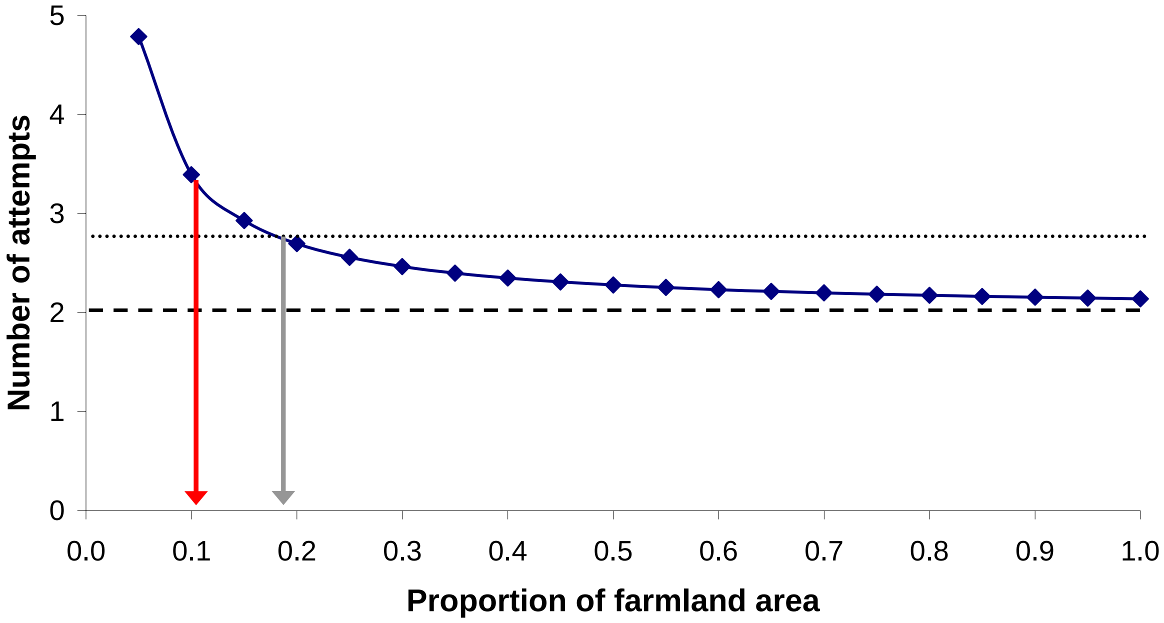
Figure 5.1. The magnitude of the key parameter required to achieve 1% population growth (curve with diamonds) in Kestrel. The dashed line is the current estimate of the key parameter, the dotted line is the maximum recorded key parameter (from Table 5.3). The shaded vertical arrow gives the minimum proportion of the population that would need to be affected by an increase in the key parameter to its maximum value if population growth were to be achieved.



If it is assumed that ELS options are placed in the lowland farmland environment at random with respect to bird distribution, then the proportion of the population required to increase its key parameter to achieve population growth (i.e. the x-axis in Fig. 5.1) can be considered equal to the area of farmland required (this is a key assumption, the implications of which are discussed in full in Appendix 5). This enables an estimation of whether the current uptake of ELS options relevant to individual species' key parameters is likely to be adequate to encourage population growth. For example, in Fig. 5.1 the key parameter would have to increase to the maximum value on a minimum of 25% of the area in order to produce a 1% annual growth rate.

For each ELS option, the probable effect on summer food, winter food and nest sites was determined for each species with reference to the literature. The total area of farmland that had options affecting each species key parameter was also determined (based on uptake data - see ELS data, Appendix 5, page 154). Note that for the purposes of this analysis we used the area of farm holdings with a particular option (rather than area of individual options). The following analyses therefore make the assumption that option effects are at the farm level. The estimate of the proportion of farmland containing options affecting key parameters can be used in conjunction with the model in Fig. 5.1 to estimate the magnitude of the key parameter that would be required to result in population growth given the area affected. This is illustrated with a further example in Fig. 5.2. The number of nesting attempts (NA) has been identified as the key parameter driving Skylark population declines in several studies. Currently, an estimated 10% of farmland will include ELS options that will have a probable positive effect on NA (see ELS data, Appendix 5). According to Fig. 5.2, this scenario, illustrated by the red vertical arrow, would require ELS options to increase NA to 3.4 (a 70% increase on the current value). The maximum value, shown as the grey arrow in Fig. 5.2, allows the above figures to be put into context. Clearly, an increase to 3.4 attempts is unrealistic as it considerably exceeds the maximum value.

Figure 5.2. The number of breeding attempts required to achieve 1% population growth (curve with diamonds) in Skylark. The dashed line is the current estimate of the key parameter, the dotted line is the maximum recorded key parameter (from Table 5.3). The shaded vertical arrow gives the minimum proportion of farmland area that would need to be affected by an increase in the key parameter to its maximum value if population growth were to be achieved. The red arrow is the current proportion of farmland area containing ELS options having probable effects on Skylark NA.



The approach taken in Fig. 5.2 was repeated for all species that have PGR of less than 1.01. Whether the required parameter estimate was achievable or not was defined in relation to the maximum value and the current rate of that parameter. If the required parameter was greater than the maximum rate (as in Fig. 5.2), the target was considered unachievable. If the required parameter was less than the maximum rate, but still a relatively large increase compared to the current rate (taken as greater than 25% increase), the achievability of the target was defined ‘possible’. Otherwise, the target was defined as achievable.

Table 5.3 presents the above classifications in relation to the proportion of area required to reach population growth when the maximum parameter is attained. There were only three species where the required parameter was considered a realistic target: Kestrel, Tree Sparrow and Reed Bunting. Table 5.3 also shows the results of the modelling exercise if ELS uptake nationally were 70%, the current target for uptake. The proportion of area covered by the relevant options has been adjusted accordingly. This high uptake resulted in more achievable required rates. However, Lapwing, Turtle Dove, Yellow Wagtail, Linnet, Yellowhammer, Reed Bunting (FPA only) and Corn Bunting (S_{FY} only) did not reach achievable targets. Furthermore, Turtle Dove had very few options that were likely to affect its key parameter, NA. Note that although Lapwing is currently increasing (at a very slow rate) and that only a very small percentage of farm area is required to affect its key parameter (FPA), there were no options under ELS that would have probable effects on FPA in this species, hence the target required rate is classified as unachievable.

BAP Targets

The modelling approach adopted so far has considered key parameters required and the area of farmland likely to deliver for certain key parameters in order to produce a 1% population growth in a subsequent year. However, smaller increases in demographic parameters may result in population growth over a longer time span (due to year-on-year population growth in that proportion of the population where the demographic parameter is increased). The models developed above were adapted to estimate the proportion of the population (and hence farm area) that would need to increase the key parameter in order to meet longer-term BAP targets for the seven relevant BAP species whose target is measured as a population trend. The baseline year for these models was set at 2003, in line with BAP targets. Results are shown in Table 5.4. In most cases the proportion required was 20%. BAP targets for Turtle Dove, Skylark, Linnet and Yellowhammer were considered unachievable under the modelled scenario. Conversely, results for Tree Sparrow, Corn Bunting (for NA) and Reed Bunting (for S_{FY}) suggested that BAP targets were achievable. As before, these proportions were also calculated assuming a national uptake of ELS of 70%. The classification of achievability of targets remained unchanged except for Skylark, which was classified as possibly achievable.

Table 5.4. Proportion of population at maximum rate required to reach BAP target, with a baseline year of 2003, where green = achievable and red = not achievable.

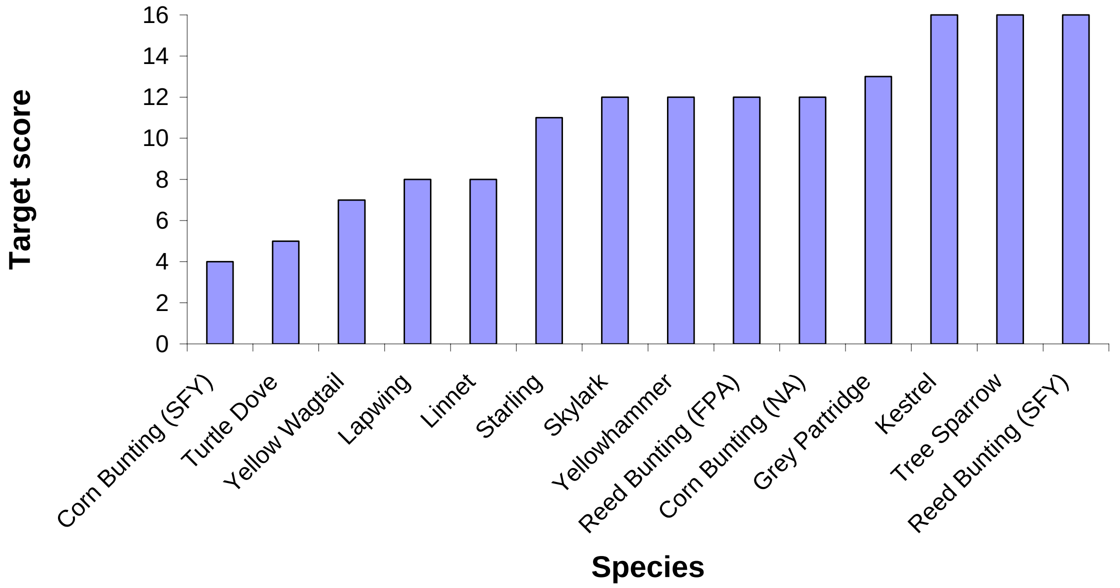
Species	**Key parm**	**BAP target**	**Proportion required**
Turtle Dove	NA	Population growth* by 2010	🟥 0.10
Skylark	NA	15% population growth by 2015	🟥 0.11
Tree Sparrow	S_{FY}	50% population growth by 2010	🟩 0.20
Linnet	FPA	15% population growth by 2010	🟥 0.19
Corn Bunting	NA	Population growth* by 2010	🟩 0.02
	S_{FY}		🟥 0.36
Reed Bunting	FPA	15% population growth by 2010	🟥 0.08
	S_{FY}		🟩 0.08
Yellowhammer	S_{FY}	15% population growth by 2010	🟥 0.35

* Taken as 1%

DISCUSSION

The modelling exercise considered ELS options to have an effect on a given species' key parameter only where such evidence existed in the literature. The procedure was therefore conservative in this respect. A second classification of potential effects, based on general ecological knowledge rather than published evidence, was also formulated. Considering 'potential' effects usually increased the proportion of farm area affected substantially and therefore there were many more species where the target was considered realistic. Exceptions were Corn Bunting (the latter for S_{FY} only) where the required rate exceeded the maximum rate, and Grey Partridge, Turtle Dove, Skylark, Yellow Wagtail, Starling and Corn Bunting where a large (>25%) increase in the key parameter would be required to result in population growth.

Figure 5.3. Target scores to assess general likelihood of ELS options increasing population growth to at least 1% per year. Scores are derived from Table 5.4 and from additional models under differing scenarios of uptake and option effect (see text), where a forecast achievable target scores 2, a possibly achievable target scores 1 and an unachievable target scores 0. Species are presented in order of ascending score, where the maximum score is 16 (i.e. the results are based on eight different scenarios).



A further assumption made in the models is that only a single key parameter will be affected and other parameters stay constant. However, it seems likely that management options that are introduced that may have a primary effect on the key parameter are also likely to affect other demographic parameters. To incorporate this possibility, further analyses were carried out assuming that all parameters increase as the key parameter increases, but by a relatively low amount taken as 1.0%. The adjustment naturally resulted in a lower proportion of the population needed to increase the key parameter to cause population increase in every species. Despite this, there were still some species where the estimated area of ELS would not be enough to increase the population: Lapwing, Turtle Dove, Yellow Wagtail, Skylark, Linnet, Yellowhammer and Corn Bunting.

The main results have focussed on the more conservative scenarios with respect to effects of ELS options, but the whole modelling exercise (including those models referred to above) has considered a range of different scenarios under which ELS options may affect key demographic parameters. A simple method of ranking species in terms of the likelihood of ELS achieving 1% growth in each species is given in Fig. 5.3. Here, each scenario considered (Table 5.3 and above) is given a score according to whether population growth is deemed achievable given the parameter estimate required and the area of relevant ELS options: 0 for not achievable, 1 for possibly achievable and 2 for achievable. Fig. 5.3 shows that Corn Bunting and Turtle Dove are the worst performing species across the different scenarios and therefore would seem the species least likely to benefit from ELS options. However, for Corn Bunting NA was also identified as a key parameter limiting population growth in this species and the targets for this option seem far more achievable. Similarly, targets for Reed Bunting FPA were often classified as possibly achievable, but the targets for a second key parameter, S_{FY}, were always achievable. Yellow Wagtail, Lapwing and Linnet were also predicted to be relatively poorly served by ELS.

This analysis represents a novel approach in assessing how much habitat is required to deliver population recovery in relation to current and predicted uptake of ELS. The approach should be viewed as a guide to assess the likelihood of delivery of population increase and therefore it may be more informative to consider the broad patterns, rather than the results of each individual species. The two key findings in this respect are: (i) the lack of certainty of delivery through grassland options – this reflects a lack of research which is to some extent already being addressed through a number of Defra-NE funded projects; and, (ii) the lack of uptake of in-field options and perhaps to a lesser extent, the more complex/demanding field margin and boundary options. Over and above these broad patterns, we consider four species, Turtle Dove, Yellow Wagtail, Lapwing and Linnet, to be poorly served by ELS. Turtle Dove requires seed-rich foraging habitats in the breeding season (e.g. conservation headlands) which have a poor uptake. Yellow Wagtail and Lapwing both require similar in-field nesting habitat options that are unpopular in terms of uptake. For Linnet however, poor forecast delivery by ELS is largely a result of the uncertainty of the value of grassland options.

8. OBJECTIVE 6: TO PREDICT LIKELY FUTURE TRENDS IN THE FARMLAND BIRD INDEX

See Appendix 6 for full text and all references (pages 183-189).

In the UK and Europe, the impacts of agriculture on ecosystem change and biodiversity loss were largely driven by policies that supported production-linked subsidies (Chamberlain *et al*., 2000; Donald *et al*., 2002). Policy reform is likely to cause further land-use change (Dwyer *et al*., 2006) and it is important that the potential impacts of these changes are explored to identify potentially vulnerable species and assess the likely degree of impact so that the changes can be managed or mitigated accordingly.

Here we use a recently published biodiversity risk assessment framework (Butler *et al*. 2007) to predict the impact of two land-use change scenarios on farmland bird populations: a) predicted declines in the area sown to (spring) barley and sugar beet in favour of winter wheat and oil seed rape, with increased block cropping (with large tracts of land under a single crop type) of these simplified rotations; and b) increased growth of biofuel crops on set-aside land. There were three key steps to this risk assessment process. Firstly, the potential detrimental impacts (hazards) associated with the agricultural change were identified. The risk assessment framework assumes that the major sources of risk to UK farmland birds will be reduced food abundance and reduced nesting success. An agricultural change will impact food abundance if it causes a change in foraging habitat availability and/or a change in prey abundance in the existing foraging habitat. It will impact nesting success if it causes a change in nesting habitat availability and/or a reduction in nest success in the existing nesting habitat. Based on expert opinion, it was determined that both scenarios are likely to lead to a reduction in the availability of over-wintered stubbles in the agricultural landscape. Any over-wintered stubbles that do persist can be expected to have reduced weed seed availability under these scenarios. The temporal changes in vegetation structure over the course of the summer will also lead to a reduction in summer foraging habitat and nest site availability due to reduced access.

The risk to each species from each land-use change scenario was then characterised by calculating risk scores based on exposure to the associated hazards. When assessing risk, the framework takes into account species' vulnerability to change, as defined by their degree of specialisation or niche breadth, and their reliance on farmland habitat. The risk score generated by the framework reflects the proportion of a species' ecological requirements affected by an agricultural change, with higher scores attributed to species demonstrating a greater proportion of affected requirements (see Butler *et al.* 2007 for a detailed description of the risk assessment framework). Whilst determining the potential detrimental impacts (hazards) associated with an agricultural change may be a relatively straight-forward component of risk assessment, determining the level of exposure to these hazards is much more difficult because it will be determined by the spatial congruence of land-use change and species' distribution. For the assessment of land-use changes reported here it was assumed that the land-use change will occur nationwide and that the entire lowland farmland population of vulnerable species will be affected. If the land-use change is likely to be spatially restricted so that only a proportion of the population of vulnerable species are likely to be exposed to the associated hazards, these predictions need to be interpreted accordingly. This is the case for spring barley and, more particularly sugar beet, both of which have restricted distributions. It is likely that the same will apply to biomass for energy crops as these will be expensive to transport and only economic within ca. 25 miles of the end user. Obviously, for changes that are likely to be more regionally specific the impact of these changes are likely to be less than national scale changes. The conclusions with respect to changing species status are, therefore, worst case scenarios.

Thirdly, these risk scores were used to link national population trends to field-scale changes in management. The risk assessment framework has previously been validated against the impacts of land-use change associated with past agricultural intensification (Butler *et al*. 2007). Using parameter estimates derived from this process, risk scores generated by the risk assessment framework can be used to predict the likely impact of future changes to agricultural systems or management practices on the annual population growth rate and conservation status of farmland bird species.

The hazards associated with both land-use change scenarios assessed here are the same so they are predicted to have the same level of impact if introduced into agricultural environments independently. Forty-two of the species included in these analyses, including 16 of the 19 species in the farmland bird index, either forage and/or nest in the cropped area of arable fields and are susceptible to exposure to these hazards. These species are therefore likely to experience reduced population growth rates under these scenarios. If either of these land-use changes occurred, three species (Meadow pipit, Wood pigeon and Kestrel) are predicted to be re-classified to a less favourable conservation status (Amber to Red, Green to Amber and Amber to Red, respectively based on the UK Birds of Conservation Concern, Gregory et al 2002). If both an increase in block cropping and an increase in the growth of biofuel crops took place, the same subset of species would be vulnerable but the predicted increase in risk to these species, and therefore degree of detrimental change in population growth rate, would be double that if either the scenarios was realised independently. If both land-use changes occurred, seven species are predicted to be re-classified to a less favourable conservation status, with Meadow pipit, Kestrel and Barn Owl all predicted to become red-listed. Again it should be highlighted that these predictions assume UK-wide land-use change and therefore exposure of the whole population of vulnerable species to these hazards.

9. OBJECTIVE 7 – RECOMMENDATIONS FOR THE DEVELOPMENT OF ES AND RESEARCH

THE TYPE OF OPTIONS WITHIN ELS

The work presented here suggests three possible additions to the suite of options under ELS

a. In-field nesting plots for Yellow Wagtail. This is an option that requires more research to develop in detail. The species is likely to require much more cover than similar plots for Skylark or (under HLS) Lapwing, although the monitoring of the use of Skylark and Lapwing plots may provide valuable information in this respect
b. A summer fallow [2]option that may serve to mitigate the potentially negative effect of the loss of set-aside on birds. Analyses presented here provide some evidence that the set-aside may have benefited birds at the population level. This may be attributable to its extent, wide distribution throughout the arable farmland (including the most productive areas) and the fact that it offers insect and plant food all year and nest sites for some species. ELS stubble and wild bird seed mixture options will provide winter food resources for birds but no options currently provide the summer nesting or feeding habitat of set-aside. This could be achieved by removing the need to follow stubble options with a spring crop to allow a summer fallow. Because of the large area covered by set-aside, it is unlikely that an equivalent area can be made available through ELS. Therefore higher quality habitats need to be created, in terms of amount and/or duration of resource provision in terms of food in winter and summer and nest sites.
c. More research into optimal options in grassland. Developing current research on options within grassland is required to increase the evidence base for what birds require in these landscapes, the scale at which they require it and the effectiveness with which resources are delivered by habitat management options.

THE QUALITY OF OPTIONS WITHIN ELS

The work presented here suggests several possible modifications to options or groups of options under ELS

a. Modifications of options designed to deliver winter seed food for birds that enhance food resources in late winter (late February and early March). This would entail retaining stubble and wild bird cover (EF6, EG4, EG5 and EF2, EF3, EG2) beyond February 15th perhaps up to early or mid March.
b. Encourage single crops within wild bird seed mixtures to be grown in separate drill widths to facilitate more effective management to maximise seed production
c. Modifications of the management of options for grass and grass and wildflower margins that increase structural heterogeneity, particularly opening up the sward to improve accessibility of prey.

In addition, research on the 'resource density' provided by different options would inform estimates of amounts required. This would be particularly relevant to options providing winter seed food, as this is depleted throughout the winter, in contrast to summer invertebrate food which is constantly replenished through reproduction and where accessibility may be more of an issue.

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[2] This term is used for convenience but relates to an option where the vegetation is allowed to develop undisturbed (except perhaps for a light cultivation in early spring). It should not be confused with the traditional (pre-herbicide) meaning of fallow, in which the land was regularly cultivated to control weeds. Should such an option be adopted, it may be advantageous to use an alternative term, such as 'land taken out of production'.

THE DEPLOYMENT OF OPTIONS WITHIN ELS

The work presented here suggests a major knowledge gap in relation to several areas of option deployment

a. There are very few empirical studies that have addressed the key issue of the scale of options required (how much of a given resource) to have an effect at the population level. The work presented here provides a theoretical framework to provide a guideline in this respect but this needs to be validated at least for some key options and species. One approach would be to capitalise on the roll out of ELS as a natural experiment and target bird and habitat research on a sub set of those 1km squares currently within the ELS evaluation programme. For example, a stratified random sample of squares with, say, high, medium and low areas of field margins or stubble options, controlling for other options present on the farm.

b. A similar approach to that outlined in 3a could also be used to consider effects of landscape context on the effectiveness of resource delivery by certain options. This could also be addressed through targeted surveys of one or two key options outside the current ELS evaluation programme

THE UPTAKE OF OPTIONS WITHIN ELS

Perhaps the most important result of the analyses presented here is that even with 70% uptake the scheme will fall short on delivering for a large number of bird species in the Farmland Bird Indicator. This could be addressed by;

a. Increasing the uptake of in-field arable options such that the balance of boundary/margin/infield options is less biased towards boundary and margin. This may require some modifications of options to make them more attractive to farmers (e.g. spraying off skylark plots as an alternative method of establishment) x or the development of a wider range of options (e.g. a modified version of HLS option HF13 (fallow plots for ground nesting birds).

b. Increasing the uptake or more complex/demanding boundary options

c. By considering the extent to which the effectiveness of options could be increased and hence the area required reduced through targeting. More effective targeting at the farm and landscape scale may be particularly valuable for less widely distributed species such as Turtle Dove and Yellow Wagtail

REFINEMENT OF THE ANALYSIS OF UPTAKE

The analyses presented here are at a national scale. More spatially explicit approaches would provide a more accurate indication of the impact of ELS on potential population changes. Such analyses could take account of:

a the distribution of the species concerned.

b the availability of the options concerned (e.g. arable options are not available in grassland areas, etc.).

c regional differences in option uptake, in areas where they are available.

APPENDIX 1 PREDICTING THE RESPONSE OF FARMLAND BIRD POPULATIONS TO AGRICULTURAL CHANGE: UPDATED REVIEW OF SPECIES-SPECIFIC AND GENERIC RESOURCE REQUIREMENTS

SUMMARY

This review shows that an extremely wide range of resources is used throughout the year by the 20 species on the farmland bird index. Some of these species can be loosely classed as "generalists", indicating that they are found in a wide variety of habitats and feed upon a wide range of food types, whereas other species have a narrower range of requirements (specialists). However, it must be borne in mind that some species that might be regarded as generalists may have specific resource-requirements during at least one stage in their life history. The Starling is an example of one such species; Starlings feed upon a wide variety of food resources in many habitats, but have a specific requirement for holes in trees or buildings for nesting, and the lack of suitable nest-sites may limit them in some regions.

Conversely, species that might be regarded as specialists may demonstrate some plasticity in their requirements. Linnets, for example, have a diet restricted chiefly to weed seeds throughout the year, whereas other granivorous birds take grain and invertebrates at different times. However, with the decline in the abundance of many important weed species in recent decades, oilseed rape now provides a large proportion of the diet of Linnets in the breeding season, thereby reducing the impact of the loss of more "natural" food resources.

Tables A1 and A2 summarise the requirements (habitats and food) of each species in summer and winter. Categories have been kept broad deliberately, and for the specific details of resource requirements readers should refer back to the relevant text sections. These tables serve to highlight that many of the 20 species have common resource requirements, and the provision of some resource categories would in fact aid many species.

Nesting sites

Trees, shrubs and hedgerows are clearly important to breeding farmland birds, with 15 of the 20 index species using them rather than (or as well as) cropped areas. However, this is one example of a conflict between the interests of different species; although many birds need boundary features for nesting and/or foraging, a few (Grey Partridge, Lapwing, Skylark) show a marked aversion to at least some boundary features. In these cases, it may be necessary to consider targeting different areas for different species. Thankfully such direct clashes between the resource requirements of different species are rare.

Foraging habitat

As for nesting sites, it is clear that certain habitats are important for a significant proportion of birds on the farmland bird index. As with nest sites, the habitats used by the greatest number of species are uncropped ones, in particular uncropped margins, rank grass and set-aside in the breeding season and margins, set-aside and stubble in the winter.

Food

The two most commonly taken food categories in the breeding season are weed seeds (taken by 11 of the 20 species) and non-soil dwelling invertebrates (15 of 20). Weed seeds remain important in the winter, with 13 of the 17 species still present in the winter taking them.

INTRODUCTION

The resources required by farmland bird species can be loosely placed into three categories: food in the breeding season, nesting sites, and food in the winter. Food and habitat are inexorably entwined, and although choice of habitat may be determined by the food within that habitat (hence it is the food choice that determines habitat use) there may be other considerations such as proximity to nest site and the risk of predation while foraging.

There may be additional requirements, such as winter roost sites, and other seasonally specific requirements, such as needs of birds during the post-fledging period. For three species (Turtle Dove, Yellow Wagtail and Whitethroat) there are considerations of their migration to and wintering in sub-Saharan Africa, but these resource-requirements are considered to be outside the remit of this report, as they are unrelated to the UK agricultural environment (although the chance of a bird surviving autumn migration may be influenced by body condition at the start of migration, which may be influenced by its breeding environment; see Turtle Dove, below).

Although resource requirements fit into these three categories, disentangling these needs is not simple. The need for one resource has to be measured against the requirements for another. For example, nesting sites will be chosen not just for their suitability for nesting per se but also for their proximity to food resources. In the following species accounts resources requirements have been separated into “breeding” and “non-breeding” season requirements. Even these two categories are not independent of each other, as the needs of a species in the winter may influence its distribution in the summer, or vice versa.

SPECIES ACCOUNTS

Kestrel *Falco tinnunculus*

Perhaps the most common raptor in the country, the Kestrel is widely distributed in Britain. The greatest concentrations occur in southeast England, particularly East Anglia, whereas the species is much less prevalent in northwest Scotland, southwest Wales and parts of southwest England. The Kestrel’s population size has fluctuated markedly in recent decades. Following a decline associated with pesticide mortality during the 1960s, the species recovered during the subsequent decade (Gibbons *et al*. 1993). However, the population then experienced a further decline during the 1980s, which was particularly pronounced in western Britain (Gibbons *et al*. 1993). Despite the population having stabilised in recent years, the species still decreased by 27% between 1970-2004 (Eaton *et al*. 2006). Because of this decline, the Kestrel is amber-listed as a species of conservation concern.

Breeding season requirements

Kestrels usually select territories with a number of alternative nesting sites, a suitable roost site and open country for hunting. They defend an exclusive territory around the nest at the beginning of the breeding season, but later in the season, the territory may expand and overlap with that of neighbouring pairs (Village 1990; Boileau *et al*. 2006). Most hunting is done within 2 km of the nest site, but the range is often much smaller, especially in years when prey is abundant (Village 1990). Although Kestrels can be found in most open countryside types, some habitats are able to support higher densities than others. The highest densities of nesting Kestrels are reached on grassland, with mixed farmland holding intermediate densities and arable farmland generally low densities. These densities may be related to the abundance of voles *Microtus* (Village 1990). In a French population, Kestrels were shown to forage in a variety of different habitats, but in particular, grazed pasture and unmanaged habitats such as fallow and set-aside grassland were preferred (Boileau *et al*. 2006). Cultivated areas were largely avoided (Boileau *et al.* 2006). Male Kestrels favoured hunting in grassland with a vegetation height between 10-15cm, in which they also had greatest prey capture success (Boileau *et al*. 2006). Vegetation heights in excess of this range may restrict accessibility to prey species, either because higher vegetation affords prey greater concealment, or because tall grass impedes their capture (Boileau *et al*. 2006). Schmidt *et al*. (2006) suggested that low intensity grazing of grassland might create the optimal habitat type for Kestrels, because the density of small mammals is still high under such a management regime, but the grass sward is low enough to allow access to prey.

Kestrels are adaptable in their use of nest sites, but do not build their own nests. Old or disused nests of Carrion Crows *Corvus corone*, Magpies, *Pica pica*, Grey Herons *Ardea cinerea* and Sparrowhawks *Accipiter nisus* are used, as are ledges on buildings and rock-faces. They are also regular hole-nesters, using natural tree-holes and also readily accepting nest-boxes. It is possible that in intensively-managed arable farmland the lack of suitable nesting sites (due to the loss of hedgerow trees) may depress Kestrel densities.

The diet of Kestrels consists largely of voles, with the most important being the Short-tailed (Field) Vole *Microtus agrestis*, which can account for up to 80% of Kestrel diet (Village 1982). Mice *Mus* and shrews *Sorex* are also preyed upon (especially the common shrew, *S. araneus*), and other mammals taken include young rabbits *Oryctolagus cuniculus*, squirrels *Sciurus* spp., moles *Talpa europaea* and rats *Rattus norvegicus*. Other vertebrates taken include small birds and lizards. The commonest bird species taken are open country nesters such as Meadow Pipits *Anthus pratensis*, Skylark *Alauda arvensis* and Starling *Sturnus vulgaris*. Fledglings of these species may be important food sources while brood-feeding, especially in urban areas (where House Sparrow *Passer domesticus* may be a very important component of diet, Yalden 1980).

Invertebrates are also taken, including caterpillars (mostly Noctuidae: Lepidoptera), ground beetles (Carabidae), dor beetles (Geotrupidae) and grasshoppers (Acrididae). In some habitats, or in years of low vole abundance, insects may be a very important component of the diet, and some authors (e.g. Simms 1961, Yalden & Warburton 1979) believe that this may have been underestimated by other studies. Riegert and Fuchs (2004) showed that recently fledged Kestrels predate a larger number of insects than do adults, which is presumably related to the poorer hunting capabilities of juvenile individuals.

Wintering requirements

Kestrels in Scotland and northern England are partial migrants, but in southern and central England, they are largely resident (Village 1990). Many northern birds winter in the Midlands and East Anglia, but a smaller proportion, particularly of first-year birds, may wander further afield to the European continent or even North Africa (Village 1990). More local movements from upland areas to lowland and coastal areas during winter also appear to be commonplace. There is little change in the habitat requirement of Kestrels in the winter. Densities generally increase in arable areas; it has been suggested that this may be due to many first-year birds migrating away from the breeding area and settling on arable land as they can obtain earthworms (Lumbricidae) from freshly tilled fields (Shrubb 1980, Pettifor 1983). Earthworms form a large proportion of Kestrel diet in the winter, especially for first-year birds, and birds will follow the plough in the autumn. Kestrels will also forage for ground beetles and other invertebrates in cereal stubbles after harvest. Voles and, to a lesser extent, small birds, remain important.

Grey Partridge *Perdix perdix*

The Grey Partridge has shown massive declines in population and range since the early part of the twentieth century. Most obviously, it has retreated from the western part of its range; it is now absent or scarce in Cornwall, Devon, Wales, NW England and West Scotland. CBC results indicate that the British population declined by approximately 75% between the two Breeding Bird Atlases (Gibbons *et al*. 1993) and Potts (1980) estimated a decline of 80% between 1952 and 1986. The principal driving force behind this decline is a decline in chick survival rates from 45% to below 30% (Potts 1980). This decline has been linked to herbicide use reducing the availability of invertebrate food for chicks (Potts 1986). Similar declines have been recorded in Grey Partridge populations throughout

Europe and North America. Grey Partridge is on the red list of Birds of Conservation Concern (Gibbons *et al*. 1996) and a UK BAP Priority Species.

Breeding season requirements

Grey Partridges are birds of open ground, having evolved on steppe grassland and subsequently adapted to the agricultural landscape. In Britain they are particularly linked to areas of cereal growing. They are sedentary, so to be suitable an area has to provide both breeding and wintering habitat.

Grey Partridges make shallow nest scrapes in dense grassy cover (preferred vegetation height is 20-60cm, Wübbenhorst and Leuschner 2006). They prefer nest sites that are above level ground, i.e. on raised ground such as a bank or hummock (Rands 1986). They also tend to avoid banks or hedges with more than 10 trees per kilometre of linear cover (Rands 1982). The availability of such sites – densely and permanently grassed, raised but away from treelines – explains most of the difference in Partridge abundance between estates (Potts 1980). Grey Partridges tend not to nest within the crop itself, but will do if more suitable sites are not available.

The home-range size of Grey Partridge during the breeding season can vary by one or two orders of magnitude, from only a couple of hectares (Blank and Ash 1956; Salek *et al*. 2003) to tens or even hundreds of hectares (O'Connor 2001; Novoa *et al*. 2006). This wide variation is almost certainly related to differences in habitat quality between the study sites. A recent study in Switzerland by Buner *et al*. (2005) examined patterns of habitat use within the home ranges of reintroduced Grey Partridge, demonstrating that wild-flower strips and (treeless) hedges (spring only) were positively selected during the breeding season. In contrast, cereals, root crops and grassland were used in proportion to their relative availability within the study area (Buner *et al*. 2005).

Predation of Partridge nests (either of the eggs or the sitting hen), particularly by foxes *Vulpes vulpe*, stoats *Mustela erminea*, weasels *Mustela nivalis*, hedgehogs *Erinaceus erinaceus*, rats *Rattus norvegicus* and Corvids (Carrion Crows *Corvus corone* and Magpies *Pica pica*) may depress population levels (Potts 1986, Dowell 1988). There is some evidence to suggest that predator control measures may result in raised Partridge numbers (Potts 1986, Tapper *et al*. 1996). A study in France by Bro *et al*. (2001) found that predation (by foxes *Vulpes vulpes*, mustelids and Hen and Marsh Harriers *Circus cyaneus* and *C. aeruginosus*) determined female survival rate.

In the early part of the breeding season the diet of (adult) Grey Partridges is mainly plant in origin, with grass and cereal leaves dominating, but clover leaves and weed seeds being preferred if available (Potts 1986). More invertebrates are taken later in the season when the chicks are being fed, but even then only about 12% of the diet is insects, mainly ants (Formacidae).

In contrast to the parent diet, chick diet is mainly animal. Ninety-five percent of food items eaten in the first week of life and 80% in the first two weeks are insects (Vickerman & O'Bryan 1979). A wide variety of species are taken, including spiders (Araneae), crane-flies (Tipulidae), ground beetles (Carabidae), weevils (Curculionidae), rove beetles (Stapylinidae), leaf beetles (Chrysomelidae), grasshopper nymphs (Acrididae), ant pupae (Formicidae), caterpillars (Lepidoptera), sawfly larvae (Symphyta), ichneumon wasps (Ichneumonidae, Braconidae), plant bugs (e.g. Delphacidae, Cicadellidae) and aphids (Aphididae). Although chicks will eat plant matter, even high protein plant food such as clover leaves are not sufficient for chick growth, so insect food is vital in the first few days of life. Annual variation in the abundance of favoured chick food insects explains 48% of variation in chick mortality (Green 1984). There is a strong body of evidence to suggest that chick starvation because of reduced food resources caused by insecticide and herbicide use is the main cause of recent declines in Grey Partridge populations (Rands 1985, Potts 1986). Measures such as conservation headlands and beetle banks are being advocated to reverse this decline (Sotherton 1991, Game Conservancy Trust 2001).

Wintering requirements

Grey Partridges remain on their breeding area over the winter, congregating in coveys of adult birds and their young. Winter densities of Grey Partridge in Scotland varied markedly between different agricultural habitats, being particularly high on fodder crops and wheat stubbles, but lower on grass and winter cereals (Hancock and Wilson 2002). At the landscape scale ($1km^2$), Grey Partridge winter occupancy was positively associated with rape and wheat stubbles, field boundary grass, bare ground and winter cereals, whereas it was negatively associated with the area of freshwater habitat (Hancock and Wilson 2002). At the field scale, the strongest positive correlations were with fodder crops, winter cereals, grass in seed, barley stubble and open, grassy field edges, while the area of Juncaceae (rushes) was negatively correlated with occupancy (Hancock and Wilson 2002). In Switzerland, wintering individuals showed a preference for hedges, wild-flower strips, rape, and stubble fields (Buner *et al*. 2005), but largely avoided cereals and grassland. Radio-tracking studies suggest that the winter home-ranges of Grey Partridge are larger than those occupied during spring and summer, which has been interpreted a consequence of changes in the social organisation of the partridge (Buner *et al*. 2005).

Polygonaceae, Caryophyllaceae, Leguminosae, Labiatae and Gramineae are the most important plant components of Grey Partridge diet in the winter (Wilson *et al.* 1997a). Within these families the most favoured foods are the seeds of bistorts *Polygonum* (especially redshank *P. persicaria*, knotgrass *P. aviculare* and black bindweed *P. convolvulus*), corn spurrey *Spergula arvensis* and chickweeds *Stellaria*, meadow grass *Poa*, cereal grain and leaves (wheat, barley, oats) and the leaves and pods of vetches *Vicia* and clovers *Trifolium*. Also taken are the seeds of dead-nettles *Lamium*, hemp-nettles *Galeopsis*, gromwells *Lithospermum* and cornflowers *Centaurea*. The availability of such seeds has declined massively in recent years, with for example black bindweed present in only 4% of cereal fields in 1982 (Chancellor & Froude-Williams 1984), and Polygonum has declined from contributing 31% of the total amount of food in Partridge crops examined in the 1930s to 2% of those examined in 1977 (Potts 1984). The same foods remain important throughout the winter, with the addition of the foliage of autumn-sown cereals, which becomes more important as grain and weed seed stocks are depleted. Moorcroft *et al.* (2002) showed that the stubble field occupancy of Grey Partridges in winter was positively associated with the percentage cover of dietary weeds and cereal grain abundance. Furthermore, the density of birds increased with the seed density on intensive wheat stubbles (Moorcroft *et al*. 2002).

Lapwing *Vanellus vanellus*

Lapwings are widely spread throughout Britain, with 83% of British 10-km squares holding Lapwings during the 1988-92 Breeding Bird Atlas survey (Gibbons *et al.* 1993). However, although widespread, Lapwing populations have declined since the mid-1950s. Nicholson (1938) estimated the Lapwing population in England and Wales as 175,000 pairs. This had declined to 123,000 pairs by 1987 (Shrubb & Lack 1991) and then a further decline of 49% occurred between 1987 and 1998 when the population was estimated as 62,923 pairs (Wilson *et al*. 2001). As a consequence of this decline, Lapwing is on the amber list of Birds of Conservation Concern (Gibbons *et al*. 1996).

Breeding season requirements

Breeding Lapwings are closely associated with farmland in England and Wales, with 95% of the total population occupying this habitat (Wilson *et al*. 2001). Wilson *et al*. (2001) used data collated during the 1998 BTO/RSPB national Lapwing survey to assess patterns of habitat selection in this species. They showed that Lapwings were characterised by a strong preference for spring tillage, while rough grazing was also favoured in some regions (Wilson *et al*. 2001). Permanent grassland was used in proportion to its availability, but ley grassland and autumn tillage were largely avoided (Wilson *et al*. 2001). In addition, habitat diversity was positively associated with Lapwing presence, reflecting the fact that mixed farming regimes provide the most suitable agricultural landscapes for this species (Wilson *et al*. 2001). Finally, it was also shown that whereas Lapwings occupied 18% of spring-tilled fields that adjoined grassland, only 5% of spring-tilled fields with no adjacent pasture were occupied (Wilson *et al*. 2001). Lapwings often favour proximate grassland habitat near their nesting site, because it is a preferred chick-rearing habitat (Wilson *et al*. 2001; but see Sheldon 2002).

In the uplands, Lapwings favour short, damp swards, rushy pastures and rough grazing. They avoid leys, improved grass and unenclosed heath/moorland (Galbraith *et al*. 1984; Baines 1988). These preferences reflect two mechanisms. First, short swards enhance the ability of the birds to see and capture prey, regardless of prey density. Secondly, damp habitats increase availability of earthworms. Indeed, Lapwings are associated with fields with small flooded areas (O'Brien 2002). However, a fine balance needs to be achieved between a field that is damp enough that worms approach the soil surface, and a field that is so damp that earthworms are effectively 'drowned' (O'Brien 2002). The apparent selection of rushes may simply reflect the association of rushes with dampness, although the habitat heterogeneity that this affords may be important for hiding nests from predators.

Lapwings are known to prefer nest-sites with short or no vegetation (Galbraith 1988; Berg *et al*. 1992). Milsom *et al*. (2000) showed that the optimum sward height for Lapwings on coastal grazing marshes was between 30-50 mm. Sheldon *et al*. (2005) demonstrated that in an arable region of England, vegetation height at the nest differed significantly between crop types, with average sward height being greatest (72 mm) in winter cereals and shortest (8 mm) in spring-sown crops. In winter cereals, specifically, crop height at the nest was significantly shorter than at random points within the same field (Sheldon *et al*. 2005). Sheldon *et al*. (2005) suggested that winter cereal sward structure is generally too tall and dense at the onset of the Lapwing's breeding season to represent a suitable nesting habitat. On agricultural grasslands, Lapwing chicks generally prefer to forage in short rather than long swards. In one study of chick foraging behaviour, Devereux *et al*. (2004) demonstrated that feeding rates declined significantly as sward height increased. As surface invertebrate abundance did not vary substantially between different sward heights in this study, the reduced prey intake rate of chicks in long swards was therefore interpreted as being a consequence of either diminished chick mobility or lower food accessibility (Devereux *et al*. 2004). It was suggested that habitat suitability could be improved for Lapwings by maintaining short areas of sward by grazing or mowing (Devereux *et al*. 2004).

Nest failure rates are often considerable in Lapwings, which has prompted the suggestion that temporal declines in reproductive success underlie recent changes in this species population in Britain and more widely across Europe (Chamberlain and Crick 2003). Several factors contribute to nest failure. In arable landscapes, farming operations such a ploughing and rolling constitute an important source of nest destruction, although the precise magnitude of nest losses varies between crop types according to the nature and timing of management practices. In particular, losses attributable to farming operations are especially pronounced in spring cereals and stubbles where agricultural activity often coincides with the peak nesting period (Sheldon 2002). For example, Linsley (1999) demonstrated that the nest failure rate observed in unsown fields (56%) was substantially greater than that of sown fields (5%). In pastoral farmland, grazing density often detrimentally impacts Lapwing breeding success. Although grazing is essential to produce swards of the requisite height and structure, the presence of livestock depresses productivity through nest trampling or disturbing breeding Lapwing. Finally, predation pressure is frequently implicated as a major cause of nest failure in the Lapwing (Sheldon 2002; Chamberlain and Crick 2003). Important predators of Lapwing nests include the Red Fox *Vulpes vulpes*, the Badger *Meles meles* and the Carrion Crow *Corvus corone* (Bolton *et al*. in press). Bolton *et al*. (2007) recently described the effects of experimental predator control on the breeding success and population dynamics of Lapwing. The authors showed that, after controlling for site-specific differences in predator densities, predator control resulted in significantly higher rates of nest survival and breeding success (Bolton *et al*. 2007). In contrast, predator control did not influence the subsequent trends of Lapwing populations, but such an effect is not necessarily anticipated, given that large-scale immigration and emigration occurs between different populations that could potentially obscure its identification (Bolton *et al*. 2007). Furthermore, Lapwings generally adopt a semi-colonial nesting strategy, and several studies have shown that increasing nest densities are associated with diminished nest predation rates (Berg *et al*.

1992; Hart *et al*. 2002; MacDonald and Bolton in press). This finding may reflect either i) that Lapwing can actively repel nest predators when nesting in high densities, or ii) that they can determine areas characterised by low predation pressure, and nest in such habitats in high densities (MacDonald and Bolton in press). Finally, within-field characteristics can also influence the likelihood of nest predation. Sheldon (2002) and MacDonald and Bolton (in press) both noted that nests further from the field boundary suffered a lower predation rate than those in closer proximity. Both authors accounted for this fact by invoking the predilection of predators to forage along linear features, and thus it was suggested that the probability of encountering a nest is less marked with greater distance from these features (Sheldon 2002; MacDonald and Bolton in press).

The diet of Lapwings consists primarily of Mollusca, Annelida, Arachnida, Orthoptera, Hymenoptera, Diptera and Coleoptera. The most important prey groups are slugs (Mollusca), earthworms (Annelida), spiders (Araneae), leatherjackets (Tipulidae larvae), ants (Formicidae), ground beetles (Carabidae), weevils (Curculionidae), click beetles (Elateridae), dung beetles and chafers (Scarabeidae), grasshoppers (Acrididae), Buprestidae and Tenebrionidae. Soil invertebrates tend to be more important in the early part of the breeding season, but as the ground becomes harder Lapwings tend to switch to feeding upon surface invertebrates (Baines 1990). Chick diet is varied, including most of the invertebrate classes listed above. Sheldon (2002.) found that the body condition of Lapwing chicks was correlated with the number of earthworm setae per gram of faecal sample, suggesting that earthworms were a desirable food for chicks.

Recent research (Sheldon 2002.) has indicated that the “option 1B” of the pilot Arable Stewardship Scheme (an overwintered cereal or linseed stubble followed by a spring/summer fallow) may be beneficial for breeding Lapwings. Breeding success in this habitat was higher than in other habitat types, (although still below that thought necessary to maintain the population at present levels) and Lapwings demonstrated positive selection for nesting in option 1B fields.

Wintering requirements

Immigrants from the continent swell the British wintering population of Lapwings in late autumn, with an estimate of at least 1,000,000 made by the 1981-84 Winter Atlas (Lack 1986). This number can vary markedly, as Lapwings make hard weather movements and large numbers may leave the country to avoid severe frost and snow (although local movements to southwest England are more usual).

Large scale changes in the wintering distribution of Lapwings have been witnessed in recent decades (Gillings 2003). Whereas previous winter surveys showed the greatest concentrations of Lapwings in central England (Lack 1986), there has been a shift in the predominant winter distribution towards the east such that many birds now winter in East Anglia (Gillings 2003). Amelioration of winter conditions appears to be driving these distributional changes, but they simultaneously have repercussions for broad patterns of winter habitat selection in this species due to the polarisation of farming across an east-west axis in Britain (Gillings 2003). Lapwing were previously known to winter largely in grassland habitats, but now most wintering Lapwing occur within the arable zone (Gillings 2003). In England and Wales, 25% of Lapwing are associated with arable crops in winter, 25% with grassland, and 15% with plough and harrow. Inevitably, there were regional disparities in habitat associations, with greater use of crops in east and west England, and more use of pasture in Wales and northern England. Relative to their availability at the national level, Lapwings exhibited the strongest positive selection for sugar beet stubbles, followed by grass pasture, other stubble and bare tillage, while there was only marginal selection for cereal crops. Cereal stubble and maize were avoided.

In a study of the ecology of wintering Lapwing in Norfolk, an arable dominated region, Gillings (2003) showed that the highest percentages of individuals foraged on cereal crops, harrowed/drilled soil, and sugar beet stubbles, whereas pasture was rarely used. The importance of cereal crops increased progressively during the winter following its increasing availability in the landscape

(Gillings 2003). However, in relation to the availability of different habitats within the study site, cereals were neither positively nor negatively selected (Gillings 2003). In contrast, sugar beet stubbles were strongly selected between November and January, while oilseed rape, sugar beet crops, ploughed soil and cereal stubbles were all avoided (Gillings 2003). Harrow/drilled soil was only selected during autumn and early winter. Gillings (2003) suggested that the majority of wintering Lapwings in the study area forage in cereal fields, which is by far the most abundant habitat type, but make opportunistic use of ephemeral habitats such as harrow and sugar beet fields as they become available.

Energetic modelling suggests that diurnal foraging may only satiate 30% of the energy demands of wintering plovers, and consequently, individuals require to feed at night to meet this energetic deficit (Gillings 2003). Interestingly, a recent study has shown that diurnal foraging habitat selection in the Lapwing might not be representative of nocturnal foraging habitat selection (Gillings *et al*. 2005). Specifically, only 22% of nocturnally feeding Lapwing fed on cereal crops, whereas 23% foraged on sugar beet stubbles and 38% fed on bean stubbles (Gillings *et al*. 2005). There was strong positive selection for sugar beet stubble throughout the season Gillings *et al*. (2005) suggested that shifts in habitat selection between day and night are probably related to the dissimilarities in predator detection, and prey availability.

Invertebrates remain the most important food resource throughout the winter, with earthworms providing a large proportion of diet. Gillings (2003) found that earthworms only comprised 13% of all prey items on arable farmland in Norfolk, but given the relative weights of earthworms and other invertebrate prey, earthworms clearly constituted the main biomass of prey items. Other soil-dwelling invertebrates eaten by Lapwing during the winter include small adult and larval Carabidae, Staphylinid beetles, and millipedes (Gillings 2003).

Stock Dove *Columba oenas*

Stock Doves are widespread and resident throughout lowland Britain (absent only from parts of Wales and north and west Scotland) (Gibbons *et al*. 1993). Stock Doves spread from a much smaller range in southern England, expanding the range north and west from the mid-19th century onwards with the expansion of arable farming (O'Connor & Mead 1984). Although there have been some recent declines and a slight range contraction the Stock Dove remains a common farmland bird.

Breeding season requirements

As a hole-nesting species, the breeding distribution of the Stock Dove is linked to the availability of trees with suitable nest sites, although if other habitat conditions are desirable then Stock Doves will nest in rabbit burrows and rock crevices, as well as in buildings. Nest boxes are readily accepted if provided. The preferred breeding habitats are woodland edges, parkland and wooded farmland, which provide a combination of mature trees likely to provide nesting sites and suitable open foraging habitats. The loss of hedgerows and trees due to recent agricultural intensification may have resulted in a limiting shortage of nest sites in agricultural habitats (Gibbons *et al*. 1993)

Diet of both nestlings and adult is almost entirely plant-based, with buds, leaves and fruits of a wide variety of plants taken at different stages of the breeding season. Amongst the 22 plant families recorded in the diet (Wilson *et al*. 1997a) bistort (Polygonaceae), goosefoot (Chenopodiaceae), chickweed (Caryophyllaceae), buttercup *Ranunculus* (Ranunculaceae) charlock *Sinapis arvensis* and cultivated *Brassica* (Cruciferae), vetch and clover (Leguminosae) are possibly the most important, although a wide range of other crop and weed species are also taken. Both seeds and leaves are taken, and the vast majority of foraging is terrestrial; Stock Doves do not spend as much time foraging arboreally as other Columbidae. Chicks are fed entirely on crop milk when very young (Cramp 1985).

Wintering requirements

There is little change in the distribution of Stock Doves between summer and winter, although as with many farmland bird species there is some withdrawal from upland areas (Lack 1986). Stock Doves gather in small flocks, and generally concentrate on arable areas. Weed seeds are the most important dietary component, with much the same species taken as listed above. Cereal grain can be the major constituent of diet in the autumn (Cramp 1985). *Brassica* seeds contribute up to 45% of the total diet in September-October and remain important throughout the winter, as do weed seeds such as bistort (Polygonaceae) and goosefoot (Chenopodiaceae). Although crop foliage is taken (Murton 1965) this is a less important part of diet than for Woodpigeons (see below).

Woodpigeon *Columba palumbas*

With a British breeding population estimated at 2,550,000 pairs (Gibbons *et al*. 1993), the Woodpigeon is the commonest of the species considered in this report. It is abundant throughout many habitats, but particularly in lowland farmland, where it can be a pest species.

Breeding season requirements

Woodpigeons are found in many habitats, but generally prefer some combination of trees and open spaces. When nesting in dense woodland or plantations (deciduous, coniferous and mixed are all used) they often feed in surrounding farmland rather than in the wood themselves. Woodpigeons are only absent from open upland, aquatic and coastal habitats, having adapted to living in urban areas (Simms 1975).

The breeding season of Woodpigeons can be extremely long, with egg-laying having been recorded in every month (Murton 1965). However most breeding activity is concentrated into summer, when Woodpigeons nest in woods, copses, treelines, hedges, scrubland and gardens. Nests are placed in tree branches or outer edges of shrubs, although they will nest on or near the ground under thick cover or on buildings (Cramp 1985).

Little or no animal food is taken by Woodpigeons, although earthworms and small insects are occasionally taken (Colquhoun 1951); instead a huge range of plant matter is taken. Depending on the season, buds, leaves, fruits and seeds are eaten. Some trees are important food species, including beech *Fagus sylvatica* (buds, flowers and seeds) (Fagaceae), ash *Fraxinus excelsior* (Oleaceae) (buds and flowers) and hawthorn *Crataegus* (Rosaceae) (buds, flowers and berries). Other plant food is taken by foraging on the ground. Leaves of many species are eaten, especially charlock *Sinapis arvensis* and cultivated *Brassica* such as oil-seed rape (Criciferae) and vetches and clovers (Leguminosae). Other plants taken include spurry *Spergula*, chickweeds *Stellaria*, mouse-ears *Cerastium* (Caryophyllaceae), buttercup and celandine *Ranunculus* (Ranunculaceae), speedwell *Veronica* (Scrophulariaceae), plantain *Plantago* (Plantaginaceae) dandelion *Taraxacum* (Compositae), nettle *Urtica* (Labiatae) and mallow *Malva* (Malvaceae). Nestling diet is much as for adults, with the addition of crop milk.

Wintering requirements

Although British Woodpigeons are largely resident, there are small-scale movements in the autumn as some birds from the north and west move south (Murton & Ridpath 1962). The largest winter concentrations occur in the large arable farming regions of south and east England, where flocks of thousands gather. There is a relatively small amount of immigration from the continent (Lack 1986).

The most important food for Woodpigeons over the winter is the foliage of crops. In the 1950s and 1960s this consisted principally of clover grown on leys. With the rapid decline of this agricultural practice in the late 1960s and 1970s Woodpigeon numbers declined. However, numbers returned to previous levels from the late 1970s onwards following the introduction of oilseed rape. The foliage of autumn-sown oilseed rape is now the most important food resource for Woodpigeons, and the area sown with this crop is the limiting factor to Woodpigeon population size (Inglis *et al*. 1990). This crop is required in the late winter, when other food resources used by Woodpigeons in the winter have been exhausted (Murton 1965). Stubbles are foraged upon in the autumn, with birds moving onto winter cereals after spilt grain and weed seeds are consumed. In addition to crops (either foliage or seeds) a large number of weed species are taken of the species listed under breeding season requirements.

Aside from feeding on crops, Woodpigeons forage upon tree seeds (oak *Quercus* and beech *Fagus sylvatica* (Fagaceae) in particular) and fruit such as hawthorn *Crataegus* (Rosacae) and elder *Sambucus* (Caprifoliaceae), although these latter food resources are usually depleted by early winter.

Interestingly, a number of studies have shown that the large part of Woodpigeon food intake is in the late afternoon (Gibb & Hartley 1957, Murton *et al*. 1963). Woodpigeons roost in large concentrations in woods and copses, as well as in smaller groups in hedgerows and isolated trees. They may travel long distances – possibly up to 65 km – to roost sites (Cramp 1985).

Turtle Dove *Streptopelia turtur*

Turtle Doves have a restricted range in Britain, being found in the south and east of the country, with very few birds in Wales, the south-west or north of the Humber. This range has contracted in recent decades (Gibbons *et al*. 1993), accompanied by a dramatic fall in numbers: there was a 70% decline in abundance in the UK between 1970 and 1998 (Gregory *et al*. 2001). This recent decline follows a long and gradual increase in both numbers and range since the mid-19th century, if not earlier (Holloway 1997). The most recent population estimate is 30,000 pairs in 2001 (Browne & Aebischer 2001), and the Turtle Dove is red-listed as a Bird of Conservation Concern (Gibbons *et al.* 1996) and a UK BAP Priority Species.

As a summer visitor, arriving in late April/early May and departing in September, a large portion of the life history of Turtle Doves lies outside the remit of this review. It is possible that past population declines, and future trends, may be in part or whole caused by factors either during migration or on the wintering grounds (the Sahel region of Africa, Cramp 1985). However, as well as affecting breeding productivity, factors on the breeding grounds may affect the body condition of birds in the pre-migration period, and hence their likelihood of reaching the wintering grounds successfully.

Breeding season requirements

Turtle Dove distribution appears to be linked to the presence of suitable nesting habitat - scrub, large hedges, small coniferous plantations and woodland edge. Intensively managed (annually cut) hedges are rarely used as nest sites. Shrubs, especially those overgrown and thorny (hawthorn, *Crataegus monogyna*, is particularly preferred), are preferred to trees as nest sites. Shrubs with climbers such as Traveller's Joy *Clematis vitalba* (Ranunculaceae), Bramble *Rubus fruticosus* (Rosaceae) and Honeysuckle *Lonicera periclymenum* (Caprifoliaceae) are preferred: 53% of nests found by Browne & Aebischer (2001) were within 0.1 m of climbers. Browne *et al*. (2004) showed that the density of Turtle Dove territories on farmland was related to the amount of suitable nesting habitat on each plot. Specifically, as the length of hedgerow and the length of woodland/scrub edge declined within farmland, the densities of doves also declined (Browne *et al*. 2004). Browne *et al*. (2005) found that mean height of nests in the BTO's Nest Record Scheme was 2.27m.

The immediate vicinity of nest sites is not necessarily important as feeding sites for Turtle Doves, as they will travel up to 10 km (on average 0.5 to 1.5 km) to forage (Browne & Aebischer 2001). In the 1960s Turtle Doves made extensive use of "natural" feeding sites. Before they largely disappeared from the agricultural landscape, fields of clover leys and hay were important feeding areas in the early part of the breeding season. Similarly, the stoked wheat and weedy pea fields used for foraging around harvest time are no longer available. Previously, Turtle Dove diet primarily consisted of weed seeds such as goosefoots *Chenopodium* (Chenopodiceae), fumitories *Fumaria* (Fumarizceae), charlock *Sinapis alba* (Cruciferae), sunflowers *Helianthus* Compositae), fescues *Festuca* (Gramineae), bistorts *Polygonum* (Polygonaceae) and medicks *Medicago* (Leguminosae) (Murton *et al*. 1964, Wilson *et al.* 1997a), with little or no exploitation of crop seeds. However, a decline in the abundance of these agricultural weeds has resulted in a shift in foraging behaviour and diet (at least in some regions, such as East Anglia). Browne & Aebischer (2001) found that Turtle Dove diet consists primarily of crop seeds, especially wheat and oil-seed rape, which Turtle Doves foraged for at "artificial" sites – spilt and stored grain and animal feed, with little foraging on "natural" habitats. When Turtle Doves did forage in natural habitats they preferred weedy areas, particularly set-aside and rough ground which receive no herbicide applications in the breeding season and were particularly rich in field pansy *Viola arvensis* (Violaceae), fumitory and chickweeds *Stellaria* (Caryophyllaceae). This current predominance of crop seeds was found for both adult (60% crop seeds, compared to 23% in Murton's 1963 study (Murton *et al*. 1964)) and chick diet (69%, compared with just 5% in 1963).

Turtle Doves feed on sites with short (about 12 cm or less) and sparse (40% or less) vegetative cover. When feeding in crops they are usually restricted to weedy strips round the perimeter, or stubbles after harvest.

The current decline in Turtle Dove numbers may be linked to the shortening of the breeding season and consequent reductions in the number of breeding attempts. In the 1960s 24% of breeding attempts were started in August, compared with 5% nowadays (Browne & Aebischer 2001). This reduction in the length of the breeding season has resulted in overall productivity nearly halving. This decline may be associated with reduced food availability and the increased distance which birds have to forage over, with the subsequent effect on adult body condition resulting in birds ceasing breeding earlier.

Barn Owl *Tyto alba*

As a relatively scarce, widespread and nocturnal species, the Barn Owl is difficult to survey accurately. In addition, it is well established that the population undergoes cyclical fluctuations related to cycles of vole populations, making comparisons between single-year surveys unreliable. Therefore there is little accurate information on population trends, although it is clear that the British Barn Owl population has declined. The national survey conducted from 1995 to 1997 produced estimates between 3,480 and 3,951 pairs for the three years in which it was conducted (Toms *et al*. 2001). These estimates are slightly down on the 4,400 pairs estimated by a 1982-85 census (Shawyer 1987) and massively down on the figure of 12,000 pairs in England and Wales derived from a survey in 1932 (Blaker 1933). Although still widespread, the Barn Owl is now rare or absent from many areas of Britain (Gibbons *et al.* 1993), and is on the amber list of Birds of Conservation Concern (Gibbons *et al*. 1996). There is evidence that organochlorine poisoning may have played a role in the decrease of Barn Owls; both breeding success and survival rates have increased since the mid-1970s, indicating a recovery from those deleterious effects (Percival 1991).

Breeding season requirements

As the English name suggests, Barn Owls commonly breed in buildings, particularly unoccupied agricultural buildings such as barns. Large tree cavities and (to a lesser extent) rock fissures and caves are also used. Just over two-thirds of all nests are in buildings (Shawyer 1987) although there are considerable regional variations with, for example, 95% of all nests in Devon being in buildings (Ramsden 1995) but birds in eastern England preferring to nest in trees (Shawyer 1987). Barns with haylofts are preferred for breeding (Cayford 1992). The loss of barns through conversion to dwellings may have had a significant effect on the availability of nest sites for Barn Owls. Ramsden (1998) found that the loss of a breeding site through barn conversion often resulted in Barn Owls abandoning an area, even though alternative breeding sites were available, thus having a disproportionately large negative effect on Barn Owls. Large, isolated and often dead trees the favoured natural nesting sites; in Suffolk dead pollarded elms are favoured, many of which are removed by farmers for safety reasons (Cayford 1992). Barn Owls will take readily to nest-boxes (Petty *et al.* 1994); the density of a population in Norfolk was raised from 15 to 27 pairs.km^{-2} by the provision of nest-boxes (Johnson 1994), indicating that the lack of suitable nesting sites was previously limiting the population.

During the summer, Barn Owls generally forage within 2 km of the nest site. Estimates of mean home range size in Britain vary from 190ha to 319 ha (Taylor 1994; Askew 2006). Within their home range, Barn Owls forage principally over areas of grassland, including rank grassland, field margins, set-aside, drainage ditches, semi-natural and unmanged grasslands. For example, in a study of foraging habitat selection in Barn Owls of the Derwent Valley, York, Askew (2006) showed that rough and set-aside grasslands were strongly favoured habitat types, whereas improved grassland, woodlands, cereal crops and horticultural areas were used relatively less frequently. This preference for unmanaged grasslands appears to reflect variation in the availability of its preferred prey items – small mammals. Comparing the abundance of Field Voles (the Barn Owl's primary prey in Britain) amongst different grassland types, Askew (2006) demonstrated that rough grassland was characterised by the highest number of voles, while set-aside grassland contained intermediate, and improved grassland the lowest number. Interestingly, in this study, sward height was an important predictor of vole activity (Askew 2006). Specifically, voles preferred a tall grassland structure (> 30 cm), presumably because it afforded greater protection from predators (Askew 2006). Furthermore, Shawyer (1987) suggested that wet grassland edges were of "supreme importance" as a foraging habitat for Barn Owls; they are particularly abundant on farmland dissected by river valleys, preferring traditional water meadows or other wise foraging along dikes, ditches and over marshes and damp moorland edges. Martínez and Zuberogoitia (2004) found that occupied Barn Owl territories in Spain were characterised by a greater abundance of habitat edges than unoccupied territories., which they ascribed to increased densities of prey in such edges.

Isolated patches of (drier) rough grassland are also favoured, including graveyards, disused railway embankments, building plots, poultry runs, disused airfields and roadside verges. The latter habitat is responsible for a high level of mortality from road-traffic collisions; Massemin & Zorn (1998) found that most Barn Owl deaths from traffic collisions in north-east France occurred along embanked highways crossing open fields without hedges. In Britain road deaths were estimated to contribute 15% of all mortality between 1955-1969 (Glue 1971), by 1982-85 this figure had reached 51.9% (Shawyer 1987).

Highest Barn Owl densities are found in mixed farmland, as a high degree of habitat heterogeneity provides a mosaic of foraging habitats and a wide variety of prey (Tome & Valkama 2001). Barn Owls are rare in areas where farming is predominantly of a single type (Shawyer 1987).

Barn Owl diet comprises mainly of small mammals, although other prey items are taken when available. A wide range of mammals are taken (see Cramp 1985) but in Britain (short-tailed) field voles *Microtus agrestis* are taken selectively (Glue 1967). Also taken are bank voles *Clethrionomys glareolus*, yellow-necked and wood mice *Apodemus flavicollis* and *A. sylvaticus* and common and pigmy shrews *Sorex araneus* and S. *minutus*. There has been a shift in Barn Owl diet in the last three decades, with a widespread decrease in the importance of common shrew, with instead more pygmy shrews, bank voles and *Apodemus* spp. being taken (Love *et al.* 2000). Other mammals recorded in Barn Owl diet by Love *et al.* (2000) included mole *Talpa europaea*, water shrew *Neomys fodiens*, harvest mouse *Micromys minutus*, house mouse *Mus domesticus* and brown rat *Rattus norvegicus*. Foraging habitat strongly influences the prey taken with, for example, birds foraging around farmsteads taking a higher than average proportion of house mice and those foraging over potato crops taking more brown rats (Cooke *et al*. 1996). Other prey groups include birds, reptiles, frogs and even fish, all of which typically provide a negligible contribution to total diet (Cramp 1985).

Wintering requirements

Most adult Barn Owls remain on the breeding territory throughout the winter, often remaining with their breeding partner. Sites suitable for nesting in the summer are also used as winter roosts, although trees are often used as roosts even in areas where buildings are used for nesting. There may be some movement, particularly in severe weather when birds in hilly regions may move to lower altitudes (Lack 1986). There is more movement from first-year birds dispersing from the natal site, although few birds disperse more than a few km. The hunting range may increase in the winter, with birds foraging up to 4 km from the roost site.

As fat reserves in healthy Barn Owls are as low as 5.4-5.6% of total body weight (Honer 1963) they are susceptible to starvation during periods of low food availability. There are growing concerns regarding the effects of second generation anticoagulant mobilised from stored fat during periods of food stress (Burn *et al*. 2002). Britain is at the northern limit of the world range of Barn Owl, and they are absent from areas of the country that typically experience harsh winter conditions. Snow for extended periods can result in prey being unavailable, leading to starvation. During such periods Barn Owls may hunt closer to farmsteads or move to coastal regions (Lack 1986). Shawyer (1987) found a close relationship between the abundance of Barn Owls in Britain and the snowcover in the preceding winter. Winters when snowcover reached or exceeded 20 days duration (using a mean from eight meteorological stations around Britain) were followed by an immediate crash in the Barn Owl population. However, this decline was less due to direct mortality (which only increases when snowcover exceeds 35 days) but to declines in vole populations caused by the severe weather.

As during the breeding season, small mammals provide the large part of Barn Owl diet in the winter. There is some variation in the diet, both between birds in different regions and between individual birds (Barn Owls show marked individual preferences in both foraging habitat and prey type, e.g. Cayford 1992) Generally field voles are taken more frequently during the winter, reflecting their greater availability in this season (Love *et al*. 2000).

Skylark *Alauda arvensis*

Skylarks breed in most open habitats, and hence are found in farmland throughout Britain. However, there has been a very rapid decrease in Skylark density since the mid-1970s Population levels declined by 60% between 1972 and 1996, (Crick *et al*. 1997), while the BBS trend for 1994-2004 declined by 10% (Baillie *et al*. 2006). This decline has not been accompanied by a decrease in range (Gibbons *et al*. 1993). A decline in populations has also been recorded in mainland Europe (Tucker & Heath 1994). Because of this decline, Skylark is on the red list of Birds of Conservation Concern (Gibbons *et al*. 1996) and a UK BAP Priority Species.

Breeding season requirements

A recent national survey suggested that the UK population of Skylarks comprises one million breeding pairs, of which 71% were associated with lowland farmland and 50% with arable land (Browne *et al*. 2000). Within arable farmland, the greatest densities are found in set-aside, with substantially reduced densities in other crop types, including winter cereals (Browne *et al*. 2000). However, because cereals constitute a far greater proportion of the agricultural landscape than set-aside, they harbour the bulk of the Skylark population in England and Wales (Donald and Vickery 2000). Autecological studies of Skylark suggest that an important factor dictating patterns of habitat selection during the breeding season is vegetation height and cover (Donald 2004; Toepfer and Stubbe 2001; Eraud and Boutin 2002). Donald (1999) suggested that an optimal vegetation height for Skylarks was 55cm, after which territory density declined. Moreover, in a German population of Skylarks, the preferred vegetation height was 15-60 cm, while the preferred vegetation coverage was 35-60% (Toepfer and Stubbe 2001). Several other landscape and field characteristics influence the probability of Skylark occupancy. Skylarks favour large fields and avoid fields with high boundary structures (Wilson 1997; Donald 1999; but see Eraud and Boutin 2002), both of which are liable to be strategies associated with predator avoidance. Furthermore, Skylark density is positively correlated with the diversity of arable field types, which suggests that the simplification of farm rotations may be one of farm rotations may be one of the causes of its recent population decline (Chamberlain and Gregory 1999).

Skylark territory densities in arable farmland often show a temporal decline during the breeding season (Schläpfer 1988; Jenny 1990; Wilson 1997). For example, Donald (1999) noted that Skylark territory densities in winter cereal approximately halved between April and July while the SAFFIE project recorded a 30% decline between April and June (Morris *et al.* in prep), in arable regions of England. Similar seasonal patterns were documented in spring-sown cereals, other crop types combined, and temporary grassland, but no such decreases were apparent in set-aside and permanent pasture (Donald 2004). These changes have generally been attributed to rapid crop development during the summer, characterised by higher and denser sward structure, which results in some crops becoming unattractive or unsuitable habitats late in the breeding season (Wilson 1997; Donald and Vickery 2000; Donald *et al.* 2001). It has been speculated that this progressive unsuitability of certain arable crops, particularly winter cereals, may underlie the Skylark's recent population decline in the UK, because it results in an considerable loss of breeding habitat late in the season, thus curtailing the length of the reproductive season and restricting the number of broods a Skylark can undertake (Donald 1999). Further evidence for this being the mechanism underlying the decline of Skylark populations has been derived from studies of the effect of Skylark plots of the density and productivity of breeding pairs in cereal fields under the Sustainable Arable Farming for an Improved Environment Study (SAFFIE, http://www.saffie.info/). The presence of Skylark plots in the field results in a higher density of breeding pairs late in the season compared with conventional cereal fields. Furthermore birds nesting in fields with these plots are able to forage to a much greater extent within those fields, whereas in the absence of such plots a large proportion of foraging trips are outside the nesting field, reducing the foraging efficiency of adult birds (Morris *et al*. 2007)

Upland and semi-natural grassland habitats also hold high densities of Skylarks during the breeding season. In the uplands, Skylarks favour short graminoid cover over moorland, and so would actually seem to benefit from the historical increases in chronic grazing pressure (Pearce-Higgins & Grant 2002). However, at greater resolution, Skylark numbers increase with increased spatial heterogeneity in grass biomass (Pearce-Higgins & Grant 2002). Therefore, as with Lapwings, variation in sward structure may be beneficial, presumably because of the ability to provide both nest sites and feeding sites, and the increased protection from predators afforded by increased habitat complexity.

Donald *et al*. (2002) demonstrated that in arable farmland, nest survival rates and the principle causes of nest failure varied as a function of crop type. Breeding attempts in set-aside suffered significantly more predation events than other arable habitats, which contributed to its relatively low survival rates (Donald *et al*. 2002). In contrast, an equivalent number of nests in cropped and non-cropped grassland were lost to both predation and other causes, which included trampling by cattle and destruction by agricultural operations (Donald *et al*. 2002). Surprisingly, nests in cereals fields demonstrated the highest nest survival rates, owing to a relatively low rate of predation, and consequently, these breeding attempts recorded the greatest mean productivity of all crop types (Donald *et al*. 2002). In cereals fields, especially those sown in winter, Skylarks increasingly constructed their nests in or around tramlines during the breeding season, presumably because with growth of the crop sward these still afforded easy access to ground level. However, proximity to tramlines significantly influenced the survival rates of Skylark reproductive attempts, with nests closer to tramlines more likely to fail during the egg phase than those placed a greater distance into the crop (Donald and Vickery 2000). A reasonable interpretation of this finding is that predators, which frequently forage along linear habitat features such as tramlines, more easily detected nests constructed on the tramline than within the crop (Donald and Vickery 2000). The SAFFIE project has shown that predation by mammals is greater when nests are situated in the crop near to grass margins, particularly in fields that also contain undrilled patches (Skylark plots), which attract more prey (foraging birds) into the cropped area (Morris & Gilroy in prep). Finally, it should be noted that not all studies of Skylark have documented similar patterns of productivity amongst different crop types. Eraud and Boutin (2002), for example, registered higher nest productivity in set-aside and lucerne, whereas nesting success was markedly lower in winter cereals, and pasture.

A study of foraging behaviour in the breeding season showed that Skylarks foraged in set-aside, grass tracks, field margins and organically-managed silage while avoiding arable crops, grazed pasture and conventionally managed silage. Of the winter cereals, wheat was preferred over barley (Wilson 2001). Preference for particular habitats for foraging is probably due to a combination of invertebrate abundance and patchy vegetation cover that allows ease of access. The dense sward structure of winter cereals prohibits easy access to food. Odderskaer *et al*. (1997) found that Skylarks nesting in cereal crops spent over 50% of foraging time in tracks despite this habitat covering a small proportion of the total agricultural landscape.

Skylark diet in the breeding season consists of a wide range of invertebrate taxa. Important amongst these are spiders (Araneae), bugs (Heteroptera), aphids (Aphididae), craneflies (Tipulidae) (both adults and larvae), soldier-flies (Stratiomyidae), hover-flies (Syrphidae), hymenopteran larvae (Symphyta), ground beetles (Carabidae), weevils (Curculionidae), leaf beetles (Chrysomelidae) and click beetles (Elateriidae). Nestling diet consists of soft-bodied invertebrates in the first few days, with chitinous prey becoming progressively more important as nestlings grow (Poulsen 1993, Wilson *et al*. 1997a). In particular, spiders, insect larvae, ground beetles, flies (Diptera) and grasshoppers (Acrididae) are important items in the diet of nestling Skylarks (Donald 2004). Morris *et al*. (2007) found that the remains of ground beetles, flies, caterpillars and spiders were well represented in chick faecal samples.

Wintering requirements

Skylarks winter mainly on farmland and coastal habitats, with the highest densities being recorded on saltmarsh (Gillings & Fuller 2001). The majority of the wintering population is found on lowland farmland. Studies have shown that Skylarks either avoid winter cereals (Gillings & Fuller 2001) or use them in proportion to their occurrence (Donald *et al*. 2001), although this usage is greater than that by other granivorous passerines (Wilson *et al*. 1996). Grassland is also avoided (Donald *et al*. 2001, Gillings & Fuller 2001). Like other farmland granivorous passerines Skylarks prefer to feed upon winter stubbles, with set-aside and broad-leaved crops also selected (Donald *et al*. 2001). Barley stubbles (which have a higher proportion of weed species) are preferred to wheat stubbles, whilst among set-aside; rotational set-aside fields hold more Skylarks than non-rotational (Buckingham *et al*. 1999, Donald *et al*. 2001). Skylark numbers are often positively correlated with soil seed density (Robinson & Sutherland 1997, Wakeham-Dawson & Aebischer 1998; but see Hart *et al*. 2002). Declines in soil seed density mean that Skylarks have to forage for a longer period of the day (Robinson 1997), which may have an effect on their susceptibility to predation (Robinson & Sutherland 1997). Furthermore, a study of nocturnal field use in France suggested that Skylarks select the same crop types in which to roost as they do to forage (Eraud and Corda 2004). Specifically, roosting densities were greatest in stubbles, while their abundance in winter cereals and bare ground was less marked (Eraud and Corda 2004).

As in the breeding season, wintering Skylarks prefer large fields with a low boundary to area ratio and without tall hedgerows or woodland bordering the fields (Robinson 1997, Donald *et al*. 2001, Gillings & Fuller 2001). Moreover, whereas many granivorous passerines favour shorter swards in which to forage during winter, Skylarks favour slightly longer swards for feeding (>10 cm; Butler *et al*. 2005; Whittingham *et al*. 2006). These preferences are presumably related to the Skylark’s specific predator avoidance strategies (Cresswell 1994).

The diet of Skylarks in the winter varies significantly between the different foraging habitats utilised. Birds on cereal stubbles and cereals feed largely on cereal products, either grain or growing leaves. Birds in grassland feed on cereal leaves, those in broad-leaved crops on broad-leaved leaves (both crop and weeds) and those in bare tillage and set-aside have more mixed diets not dominated by any one food type (Donald *et al*. 2001). Despite higher food availability on organic farms Skylark densities are not higher on such farms (Chamberlain *et al*. 1999); this may be due to the smaller field sizes and higher field boundaries found on such farms. Skylarks take few invertebrates in any habitat. The selection of winter stubbles as the preferred foraging habitat is probably linked to the availability of cereal grain, the most energetically profitable winter food for Skylarks (Green 1978).

Yellow Wagtail *Motacilla flava*

The Yellow Wagtail is a summer visitor to Britain, wintering in sub-Saharan Africa (Cramp 1988) and returning to Britain in April. It occurs as far north and west as southern Scotland, and south-west England respectively, but the greatest concentrations are found along the coastal fringes of south-east England, in the east Midlands and the Fens of Cambridgeshire and Lincolnshire. In recent decades, this species has experienced marked declines in abundance and range in Britain, and more widely across Europe (PECBM 2006). Trends derived from the CBC suggest that the Yellow Wagtail decreased by 64% between 1978-2003 (Baillie *et al*. 2006), but the magnitude of the decline appears to vary between habitats, being especially dramatic in wet grassland and marginal upland areas (Henderson *et al*. 2004, Wilson and Vickery 2005; Baillie *et al*. 2006). Moreover, its range contracted between 1968-72 and 1988-91, with birds disappearing from parts of coastal south England, and farmland in Dorset, Hampshire and Wiltshire (Gibbons *et al.* 1993). These changes have prompted the Yellow Wagtail to be categorised as an Amber List species, and would now qualify for Red List Status.

Breeding season requirements

Yellow Wagtails are often associated with water, but this is not an essential requirement and many birds breed on dry arable farmland in the UK. Preferred habitats include along river valleys, in water meadows, in water meadows (both freshwater and brackish) and damp fields. Mason and Lyczynski (1980) demonstrated that 52% of nests were close to water, and that 67% were in grassland. In a grassland-breeding population on the Nene Washes, breeding territories were associated with fields previously subject to protracted winter floods and those containing small water features (i.e. ponds or ditches; Bradbury and Bradter 2004). The occurrence of winter flooding was seemingly favourable for Yellow Wagtails because it influenced the architecture of the grassland habitat, creating a sparse sward with a considerable proportion of bare earth interspersed between the sward (Bradbury and Bradter 2004). Areas of sparse, low vegetation are ideal foraging habitats for this species (Nelson 2001; Bradbury and Bradter 2004). In contrast, nests were generally associated with taller swards, presumably because they afford greater concealment (Bradbury and Bradter 2004). These finding suggest that Yellow Wagtails require heterogeneous sward heights within single fields to provide the appropriate foraging and nesting habitats (Bradbury and Bradter 2004). However, as intensive management practices encourage the growth of dense, uniform swards, much agricultural grassland is now unsuitable as nesting and foraging habitat for Yellow Wagtails, and this loss of habitat may elucidate the especially pronounced declines of this species on wet grassland. Furthermore, the frequency and date of grass cutting is important for birds nesting in agricultural grasslands, particularly silage. Wilson (1991) found that up to 33% of nests in a study site in the Yorkshire Dales failed due to grass cutting before nestlings had fledged, and recommended that delaying cutting by one or two weeks would have enabled this problem to have been avoided. Similarly, ADAS (1995) found that 25% of 83 nests studied in the Pennine Dales ESA were lost to cutting operations in June & July.

Although traditionally viewed as a bird of wet grassland, the Yellow Wagtail has increasingly bred in arable farmland during the last century. Mason and MacDonald (2000) examined the habitat associations of farmland-breeding wagtails in Essex and showed that they favoured spring-sown crops (73% of territories), particularly potatoes, whereas autumn-sown crops and grassland were avoided. However, the situation may be more complex than portrayed in this study. Gilroy (2006) demonstrated a mid-season shift in the habitat associations of Yellow Wagtails in a population in East Anglia, with breeding territories being most closely associated with autumn-sown crops in early May, but an increasing preference for potatoes with the progression of summer. This shift was interpreted as autumn-sown crops becoming less favourable as their increasing sward height and density limited ground access (Gilroy in press). Gilroy (2006) speculated that because autumn-sown crops dominate much of the arable landscape in Britain and Europe, a lack of suitable breeding habitat in late summer may curtail the breeding season of Yellow Wagtails, as is the case in Skylarks. Breeding territories were positively and negatively associated with other habitat characteristics in this study. Crop diversity at a landscape scale was preferred by Yellow Wagtails (Python 2006; Gilroy 2006), presumably because a mosaic of habitat types offers greater foraging and nesting opportunities. In addition, hedges were avoided, while peaty, organic soils were favoured over other soil types. Further investigating this latter finding, Gilroy (2006) showed a strong relationship between wagtail breeding distribution and soil penetrability, with softer soils having higher densities of territories. The precise mechanisms underlying this association are as yet unknown, but may be related to the fact that soil structure, possibly as a function of soil organic matter content, influences prey abundance or affects the ease of nest construction (2006). In a small Swiss population of Yellow Wagtails, there was a greater density of breeding territories in courgette plantations, closely followed by potato fields, but cereal crops were avoided (Python 2006).

Nest predation rates of Yellow Wagtail varied according to crop type and nest placement within the crop. The likelihood of predation correlated with proximity to the nearest field edge, with more predation occurring at distances within 60 m from the boundary, than beyond (Gilroy 2006). Correspondingly, Yellow Wagtails showed a strong avoidance of areas within 60 m of the field edge for nesting, while strongly preferring distances exceeding 100m in both wheat and potato crops. Additionally, in autumn-sown wheat, the probability of predation was greater closer to tramlines than further away. This can be explained by the fact that predators frequently forage along tramlines, and nests in greater proximity to the edge are more likely to be detected (Gilroy 2006). However, Yellow Wagtails, as with Skylarks, frequently place nests very close to tramlines - as these provide the only ground-access points within the otherwise dense and uniform crop. Hence crop structure restricts birds to nest in areas where predation risk is high. Nests in field bean crops experienced particularly high predation rates, compared to other crop types (Gilroy 2006). As bean crops gain height, abscission of the lower leaves results in an increase in horizontal visibility at ground level, which will facilitate detection by predation (Gilroy 2006). In contrast, visibility decreased with height in other crop types.

Yellow Wagtails generally prefer to feed in open habitats with low vegetation. In arable farmland in eastern England, Yellow Wagtails demonstrated a strong preference for foraging along tracks or near ditches (Gilroy 2006). Individuals provisioning chicks during June used wheat, potatoes and bean crop approximately in proportion to their availability within the environment, but showed a strong aversion to set-aside, oilseed rape and sugar beet (Gilroy 2006). In contrast, there was a seasonal shift in foraging habitat preferences, with wagtails provisioning chicks during July favouring potato crops, while largely avoiding winter-sown wheat. This may be related to the growth stage of the winter wheat (leaves dying off and crop ripening) rendering it less suitable as a foraging habitat for Yellow Wagtails (Gilroy 2006). Foraging efforts are generally concentrated with a radius of 130m of the nest-sites (Python 2006), although occasionally adults will travel up to 1 km to exploit foraging opportunities.

The diet of both adults and chicks consists almost entirely of small invertebrates (Davies 1977). In the early part of the breeding season (shortly after arrival from Africa) Yellow Wagtails in Oxfordshire took almost all Diptera, and 86% of the diet consisted of midges (Chironomidae). By May this proportion had dropped to 35%, with a further 44% of the diet consisting of Drosophilidae (Davies 1977). Diptera and Nematocera are important prey throughout the breeding season, as are spiders (Araneae) (Gibbons *et al*. 1993).

Davies (1977) found that nestlings were fed mainly on aphids (Homoptera) and a variety of Diptera, including blowflies (Calliphora), robber-flies (Asilidae), crane-flies (Tipulidae), dung flies (*Scathophaga stercoraria*, amongst others) and house-flies (Muscidae) and weevils (Curculionidae). Gilroy (2006) found that flies, beetles and damselflies (Zygoptera) were important constituents of the nestling diet in a population of Yellow Wagtail in Lincolnshire. This study also noted seasonal changes in the composition of nestling diet, with early broods being fed a greater proportion of beetles, while later broods were provisioned more damselflies (Gilroy 2006). Python (2006) noted that Yellow Wagtails in Switzerland largely fed their offspring with large caterpillars (46%), with Coleoptera, spiders and Nematocera all supplementing the diet.

Whitethroat *Sylvia communis*

As a summer visitor to this country, a large proportion of the Whitethroat life history lies out with Britain. It may well be that factors on the wintering grounds (or during migration) determine British population levels. This was dramatically illustrated in 1969 when three-quarters of the breeding population failed to return from the sub-Saharan wintering grounds due to drought there (Winstanley *et al*. 1974). Since that decline, numbers have gradually increased, but still remain well below pre-1969 levels.

Whitethroats are present throughout most of England and Wales, although scarce or absent in upland areas. In Scotland most are present in the south and east, with birds further north concentrated in the lowland coast fringes.

Breeding season requirements

Whitethroats are particular in their choice of breeding habitat, preferring scrub habitats at a particular stage of succession (Fuller 1982). Therefore they breed in young woodlands, recently coppiced woodland, open scrubland and hedgerows. A study of BTO nest record cards (Mason 1976) showed that 56% of Whitethroat nests reported were in scrubland, with only 18% in hedgerows. However, hedgerows are considered to be an important nesting habitat for Whitethroats and the loss of hedgerows due to agricultural intensification may have been a contributing factor to declines, or rather may have slowed the recovery from crashes caused by conditions on the wintering grounds. Evidence that this may be the case is provided by the slower recovery of breeding numbers on farmland than in riparian habitats where there has been less habitat change (Crick *et al*. 1997).

Stoate & Szczur (2001) found that the presence of Whitethroats on farmland hedges could be predicted by the height of the hedge and the width of the uncropped margin adjoining the hedge, with low hedges and wide margins increasing the likelihood of Whitethroat presence. Whitethroats usually nest in herbaceous vegetation alongside hedges, rather than in the hedges themselves, so the presence of such uncropped vegetation may be as important as the presence of a hedge. Whitethroat densities are higher on arable land, and it may be that this is due to the effect of grazing depressing herbaceous growth adjacent to hedges. Over half of Whitethroat nests recorded by the BTO nest record card scheme were in bramble *Rubus* (Rosaceae) or nettle *Urtica* (Urticaceae); grass is also used freely (Mason 1976). Nests are usually below 1 m from the ground (Persson 1971).

The diet of Whitethroats consists primarily of insects, although in late summer both adults and first-year birds may take berries e.g. bramble *Rubus* (Rosaceae), elder *Sambucus* (Caprifoliaceae), buckthorn *Rhamnus catharticus* (Rhamnaceae). The range of invertebrates taken during the breeding season is wide, but several groups predominate, notably Lepidoptera, Coleoptera, Diptera, Hymenoptera and Hemiptera. More than half the diet is Lepidoptera, both adults and caterpillars, most of which are gathered within 30 m of the nest (Stoate *et al*. 1998). Other major prey items include sawfly larvae (Symphyta), weevils (Curculionidae), ground beetles (Carabidae) crane-flies (Tipulidae) and spiders (Araneae). Diet may change through the breeding season with, for example, carabids being important in the early part of the breeding season and Hymenoptera such as ants (Formacidae) more so later in the season (Cramp 1992). Nestling diet contains a higher proportion of soft-bodied prey, in particular caterpillars and spiders (Macdonald 1979, Moreby & Stoate 2001).

Jackdaw *Corvus monedula*

Jackdaws are present throughout most of Britain, being absent only from north-west Scotland. This absence is related to a preference for lowland areas; Sitters (1988) found that few nested above 350 m (and none above 450 m) in Devon. Although there have been declines and range losses in a few areas (Gibbons *et al*. 1993), there has been a steady population decline over the second half of the 20th century, with Common Bird Census data indicating an increase of 80% between 1970 and 1998

(Gregory *et al*. 2000). The most recent estimate of the British population was 390,000 territories (Gibbons *et al*. 1993); numbers may have increased since that estimate.

Breeding season requirements

The vast majority of Jackdaw nests are in cavities, either in tree holes, rock crevices or in buildings (commonly in chimneys), although domed nests built of stick have been recorded (Gibbons *et al*. 1993). Due to this requirement Jackdaws are often found clustered in loose colonies at sites where multiple suitable nest-sites are available; a study in Oxfordshire found no preference for clumped or solitary nest-boxes (Heeb 1991). Jackdaws territories consist of the nest and immediate vicinity only. Often colonies are found in free-standing or grouped mature trees, small copses and avenues rather than in woodland. As Jackdaws will travel considerable distances to forage (Cramp & Perrins 1994) the habitat in the immediate vicinity of the nest is not of crucial importance, hence Jackdaws can be found breeding in a wide variety of habitats where suitable nesting sites are available. However, they prefer semi-open habitats and show a marked preference for foraging on grazed grasslands during the breeding season, although swards above 15-20 cm high are avoided (Strebel 1991). Therefore Jackdaws are commonest in areas of pasture or mixed farmland – a decline in East Anglia in the 1960s may have been due to the conversion of grass leys to permanent arable (Tapper 1981).

Diet in the breeding season comprises of a wide range of invertebrates, taken mainly on the ground. Unlike Rooks, Jackdaws tend not to probe for soil-dwelling invertebrates but pick up surface- and sward-dwellers, as well as foraging in and underneath dung (Lockie 1956). Prey includes weevils (Curculionidae), ground beetles (Carabidae), ants (Formacidae), spiders (Araneae), grasshoppers (Orthoptera) and many more (see Cramp & Perrins 1995). Caterpillars (Lepidoptera) may be foraged for in tree foliage (Coombs 1978). In addition, plant matter may be important, with cereal grain (from feeding troughs if not available in fields), weed seeds, tree seeds and fruit are all taken if available. Jackdaws have been recorded feeding on a long and varied list of other food resources ranging from the pirated contents of milk-bottles to bats, eggs and both chicks and adult birds (Cramp & Perrins 1994).

Nestling diet is predominantly invertebrate; a study in Wales found that Lepidoptera larvae, Coleoptera and Diptera together contributed nearly 70% of total nestling diet (Richford 1978).

Wintering requirements

There is some withdrawal from upland regions, but otherwise the distribution of Jackdaw is the same in the winter as for summer (Lack 1986). As in the summer, grassland is favoured habitat, but Jackdaws are also commonly found in stubbles and freshly ploughed ground. Fifty-eight percent of observations of foraging Jackdaws made by Waite (1984) were on grassland and stubble. Studies on field use by birds in grassland landscapes of Devon and Cornwall suggested Jackdaws prefer to forage on short swards often associated with relatively intensively managed fields (Atkinson *et al* 2005). Jackdaws will also feed on rubbish tips more readily than other Corvids and are a familiar site in towns, parks and gardens scavenging on any available food (Lack 1986).

Although surface dwelling invertebrates such as weevils remain important throughout the winter, the proportion of plant matter in the diet increases during the winter. Grain can be very important, providing the main part of the diet in some regions (Holyoak 1968). Other crops such as peas, beans and root crops are also foraged upon when available. Fruits are important in the autumn; weed seeds may be so later in the winter (Cramp & Perrins 1994). As in the breeding season, Jackdaws are opportunistic feeders and will take a wide variety of food types.

Jackdaws generally gather in central roosts in the winter (usually in woods or copses) that they may travel considerable distances to attend, often in the company of Rooks.

Rook *Corvus frugilegus*

Rooks are found in all lowland farmland regions of Britain, being only absent from upland areas such as north and west Scotland, parts of Wales and the Pennines. They breed up to 450 m in altitude in England (Yapp 1962). They are resident, with little evidence of any movements between summer and winter. The most recent Rook survey estimated there were 1,270,000 pairs of Rooks in the United Kingdom in 1996 (Marchant & Gregory 1999), which was an increase of 40% from 1975-77. This 1975-77 level was 43% less than that in 1943-46 (Sage & Vernon 1978).

Breeding season requirements

Rooks nest colonially in rookeries, averaging 30 pairs per rookery. Rookeries are in the tops of fairly tall trees, either on woodland edges or preferably in clumps or lines – treelines and farmland copses are particularly favoured. In lowland areas, deciduous trees are preferred (70% of rookeries in England are in deciduous trees, Marchant & Gregory 1999), with oak *Quercus* (Fagaceae), sycamore *Acer pseudoplatanus* (Aceraceae) and ash *Fraxinus excelsior* (Oleaceae) being favoured species.

There is some disagreement between studies in the relationship between Rook numbers and agricultural land management. All studies agree that numbers of Rooks increase with an increasing proportion of grassland in the landscape: Griffin (1999) found that Rook breeding density with 5 km grid squares in County Durham was related to the area of grassland. Lomas (1968) found that declines in Rooks numbers in the 1960s were greatest in areas of cereal growing. However, Brenchley (1984) found that Rook numbers increased as the proportion of grassland increased up to 55% of the total agricultural area, but decreased at levels thereafter: the optimum balance of land-use for Rooks was 55% grass and 45% arable. This suggests that there could be some requirement for arable as well as grassland, and that mixed farmland would provide the best habitat for Rooks. Both Chater (1996) and Griffin (1999) found that Rook density was positively correlated with (sheep) stocking density, probably because shorter swards allowed greater access to soil invertebrates for Rook feeding on grassland. Most Rooks forage within 1km of the rookery (Kasprzykowski 2003; Mason and MacDonald 2004).

The diet of Rooks during the breeding season is varied, but earthworms (*Lumbricus* and *Allolobophora* spp., Lumbricidae) and leatherjackets (Tipulid larvae, Tipulidae) are the most important prey (hence grassland is the most important habitat for foraging during the breeding season, Feare *et al*. 1974). Rooks breed earlier than other lowland Corvids, and it is possible that this is so nestlings can be fed earthworms before drying ground results in earthworms becoming less accessible. A wide variety of other invertebrates are taken, including weevils (Curculionidae), dung beetles (Scarabaeidae and Hydrophilidae), ground beetles (Carabidae), Lepidoptera (both adults and caterpillars), spiders (Araneae), rove beetles (Staphylinidae) and ants (Formacidae) (Holyoak 1972, Cramp & Perrins 1994) with surface dwelling invertebrates becoming more important as the breeding season progresses. Nestling and fledgling Rooks feed almost entirely on invertebrates, but adults do feed on grass leaves, potatoes and other root crops, legumes and weed seeds (such as bistorts *Polygonum* (Polygonaceae), violets *Viola* (Violaceae) and buttercups *Ranunculus* (Ranunculaceae)). In addition Rooks will forage on carrion, human waste, spilt food at piggeries and other ephemeral food resources. Rooks characteristically glean recently-harvested silage fields, presumably taking damaged or exposed invertebrates.

Unlike most resident farmland species, Rooks have greater difficulty obtaining sufficient food in the summer than in the winter, and starvation is a real threat later in the summer (Dunnet & Patterson 1968). This mortality is particularly marked on juvenile birds, and can be higher in hot dry years when soil invertebrates are less accessible.

Wintering requirements

As with summer foraging habitat selection, Rooks also show a distinct preference for (grazed) pasture during the winter period (Waite 1984; Wilson *et al*. 1996; Mason and MacDonald 2004), where they seem to favour relatively short swards (Atkinson *et al*. 2005). Wintering Rooks largely avoided clean cereal stubbles (Waite 1984; Wilson *et al*. 1996), but weedy stubbles were shown in one study to be favoured foraging habitats, particularly in early to mid winter (Mason and MacDonald 2004). Similarly, most studies have demonstrated an aversion to ploughed land, but Mason and MacDonald (2004) showed that when harrowed to produce a seedbed, it became a preferred feeding habitat in early winter to mid winter. Winter cereals, although foraged on by Rooks, were used less than expected according to their availability in the landscape (Waite 1984; Wilson *et al*. 1996; Mason and MacDonald 2004).

It is thought that Rooks rarely suffer hardship in the winter (Feare *et al*. 1974). The winter diet, as in the summer, is varied, but still contains a high proportion of invertebrates as listed above. Earthworms are particularly important prey. House-flies (Muscidae) are a surprisingly common winter food, probably as Rooks forage on rubbish dumps and manure heaps where house-flies are present throughout the year. In addition to invertebrates, plant food is much more important to Rooks outside of the breeding season. Cereal grain is taken from standing crops at the end of the summer, and then from stubbles and finally from autumn sowings. Root crops are also commonly foraged upon.

Carrion can be an important component of diet, particularly in winter, and the increase in animal road casualties due to more road traffic has been suggested as one factor contributing to the recent increase in Rook numbers (Marchant & Gregory 1999).

A notable feature is their use of traditional roost sites, which thousands of birds may gather at, along with other Corvids. Rooks arrive at these gatherings along set flight-routes, often with pre-roost gatherings on the way, and may travel upwards of 20 km to roost. Roost-gatherings usually consist of birds from all the rookeries within the “catchment area” of the roost. Somewhat strangely, birds from a particular rookery may travel long distances to a communal roost site despite one being present considerably nearer the feeding area (Griffin 1999).

Starling *Sturna vulgaris*

One of the most widespread and numerous of all British bird species, Starlings are present in almost all habitats, with the exception of moorland and mountains. Therefore, they are found throughout Britain, apart from areas in north-west Scotland and smaller gaps in Wales and northern England (Gibbons *et al*. 1993). However, the Starling has experienced a steep population decline across Britain in recent decades. Estimates derived from the CBC suggest a 50% reduction between 1964 and 2000, with decreases being most pronounced in the south and west of Britain and in areas of livestock farming (Robinson *et al*. 2005). As a consequence of the magnitude of the decline, the Starling has recently been added to the red list of Birds of Conservation Concern (Gregory *et al*. 2002).

Breeding season requirements

Starlings are hole-nesters, and so require suitable holes or crevices for breeding. Such nesting sites may be found in buildings, trees or nestboxes. Birds will nest in other situations, such as inside old nests of Carrion Crows *Corvus corone* (amongst others), but those in holes lay larger clutches and have higher breeding success (Feare 1984). The large-scale loss of hedgerows and hedgerow trees could mean that the availability of nesting sites limits the abundance of Starlings on farmland.

Starlings show a very strong preference for foraging on grassland, taking invertebrates from the ground surface and probing in the first few centimetres of soil. They prefer foraging in short sward grasslands (Atkinson *et al*. 2005) Moreover, whilst foraging on grassland, Starlings often associate with herds of cattle, predating insects flushed from the vegetation by the movements of the ruminants. Observations in southern Sweden have shown that Starlings occurred significantly more often in pastures with than without cattle, and also more often with active than resting cattle (Källander 2004). The importance of sufficient pasture in the vicinity of breeding Starlings has been demonstrated by a recent study. The reproductive success and breeding density of Starlings in Sweden was positively related to the availability of pasture within 500m of the colony (Smith and Bruun 2002). Where the availability of pasture in the surrounding landscape was low, provisioning adults had to forage at sites more distant from the nest, which resulted in a reduction in the feeding frequency to nestlings (Bruun and Smith 2003). These findings supports the idea that declines in the availability of permanent pasture may underlie, in part, the decline of the Starling in Britain and more widely across Europe (Tianen *et al*. 1989; Smith and Bruun 2002).

Starlings take an extremely wide variety of foods and are able to change diet to take advantage of ephemeral resources, such as waste food material from humans. However, they are primarily invertebrate feeders, taking larvae of Lepidoptera, Diptera, Hymenoptera and Coleoptera, particularly the larvae and pupae of craneflies, especially *Tipula paludosa* (Tipulidae), march-flies (Bibionidae), ants (Formicidae), ground beetles (Carabidae) and snipe-flies (Rhagionidae). Adult insects are also taken, including ground beetles, weevils (Curculionidae), rove beetles (Stapylinidae), spiders (Araneae) and earwigs (Dermaptera). Little plant matter is taken in the summer, although in the late summer birds begin to feed on fruit. This is particularly true of juveniles, which in general are more arboreal than adults after fledging (Taitt 1973).

Nestling diet tends to be far more restricted than that taken by adults, and in Britain is dominated by cranefly larvae (leatherjackets) (Whitehead 1994). In Italy, juveniles were provisioned largely with Coleoptera larvae, followed by Gastropods, Coleoptera adults, earthworms (Lumbricidae), Myriapods, and spiders (Araneae; Trotta 2001).

Wintering requirements

The British population of Starlings is swelled in the winter by a huge number of immigrants from the continent. These birds gather in huge (and often well-known) roosts in conifer plantations, evergreen shrubberies and reedbeds as well as in urban areas roosting on buildings, bridges and other man-made structures, in order to minimise predation risk and to gain energetic advantages. Birds may travel up to 38 km to attend roost sites (Feare 1984).

Clergeau and Fourcy (2005) examined the landscape composition around winter roost sites in Brittany, France, and showed that at a 2 km radius, there was a significantly higher proportion of pasture in the vicinity of roost sites than around random points. This suggests that pasture is also an important foraging habitat during the winter period (Clergeau and Fourcy 2005), a finding that is supported by other observational studies of grass field habitat use during the winter (e.g. Atkinson *et al*. 2005). Similarly to the summer period, Starlings favour foraging on short swards (Atkinson *et al*. 2005). Devereux *et al*. (2004) showed that captive Starlings spent 30% more time feeding in the short grass than long grass experimental treatment. Starlings captured more prey on short swards, but this simply reflected the greater time spent foraging in this particular sward height (Devereux *et al*. 2004).

Outside of the breeding season the reduced availability of invertebrate means that Starlings take a wider range of plant food, although they still forage for buried larvae (especially tipulids) and earthworms, with short turf remaining the preferred foraging habitat (e.g. Atkinson *et al*. 2005). Fruit eaten include yew *Taxas baccata*, ivy *Hedera helix*, hawthorn *Crataegus* spp., elder *Sambucus* spp. and especially dogwood *Thelycrania sanguinea* (Snow & Snow 1988). Fallen fruit waste in orchards is also taken. Cereal grain may also be important if invertebrates are scarce, as are weed seeds (from the ground). As mentioned before, the opportunistic nature of Starlings means that they frequently forage in gardens, both rural and urban, and on rubbish tips and other places where human waste is accessible. Starlings can adapt physiologically rapidly in response to digestive challenges of new food resources (Al-Joborne 1979).

Tree Sparrow *Passer montanus*

Tree Sparrows are a tree nesting species found in hedgerows, parkland and open woodland, although not in dense forests. Despite the scientific name, it is a lowland species, commonest in a band across mid-England from East Anglia into east Wales. It is scarce along the south coast away from Kent, absent from the south-west, and in the north confined mainly to the east (Gibbons *et al*. 1993). Numbers of Tree Sparrows in Britain have fluctuated since at least 1860 (Summers-Smith 1989, Holloway 1997), with a high population from the 1880s to the 1930s followed by a decline, and then another peak during 1960-1978. Since 1978 numbers have declined by 96%, leading to the Tree Sparrow being red-listed as a Bird of Conservation Concern (Gibbons *et al*. 1996) and a UK BAP Priority Species.

Breeding season requirements

Tree Sparrows are associated with trees, but not with dense woodland: they are found in farmland with tree-lines or hedges with isolated trees, as well as in parkland and open woodland. In a Leicestershire population, Tree Sparrows showed a marked preference for breeding sites adjacent to wetland rather than those on farmland (Field and Anderson 2004), a finding that has been replicated at broader geographical scales (Gregory 1999). This association, however, appears to be a comparatively recent phenomenon, as the species was widespread across a range of lowland habitats in the UK in previous decades (Field and Anderson 2004). Tree Sparrows nest in loose colonies of up to 50 pairs, spread over between 1 and 30 ha – the proximity of nests is determined by the availability of nest sites. Although colonies are usually loosely clustered rather than densely packed, if suitable nesting sites are available in close proximity they will be used as Tree Sparrows show no territoriality outside of the nest (Summers-Smith 1995). As hole nesters, Tree Sparrows may be limited by the availability of nesting holes. Tree holes are the most frequently used location, but buildings are also used, as are stone walls. Small holes of approximately 30 mm are preferred (Löhrl 1978). In the absence of holes, Tree Sparrows may nest within large stick nests i.e. of Grey Herons *Ardea cinerea* and Carrion Crows *Corvus corone* (Harrison *et al*. 1982).

Tree Sparrows in Leicestershire used aquatic habitats and woody vegetation for foraging significantly more often than expected on the basis of the available habitat area, while grazed grass and set-aside were largely avoided (Field and Anderson 2004). Barley and oilseed rape were used in proportion to their availability (Field and Anderson 2004).

Adult Tree Sparrows take a mixed diet in the breeding season, foraging on the ground for both invertebrates and weed seeds. Fat hen *Chenopodium album* (Chenopodiaceae) and knotgrass *Polygonum aviculare* (Polygonaceae) are favoured weed species, along with other Polygonum spp., common amaranth *Amaranthus retroflexus* (Amaranthaceae), chickweed *Stellaria* (Caryophyllaceae), forget-me-not *Myosotis* (Boraginaceae) and grasses (Gramineae) (Grűn 1975). Cereal grain becomes more important later in the breeding season, with oats especially preferred (Keil 1973). Invertebrate prey types include Lepidoptera, Hemiptera, Diptera, Coleoptera and Orthoptera. Within these orders favourites include spiders (Araneae), aphids (Aphididiae), grasshoppers (Acrididae), crickets (Gryllidae), bush crickets (Tettigoniidae) and weevils (Curculionidae) (Wilson *et al*. 1997a). Recent research at Rutland Water (G. Anderson pers. comm.) suggests that the edges of aquatic habitats are important foraging sites for insect food (especially for the larvae of aquatic insects).

In contrast, nestling diet consists almost entirely of invertebrates. Common insect food in a population foraging largely in wetlands habitats included adult midges (19.6%), damselfly nymphs (10.6%), beetle adults and larvae (10.4% and 10.3% respectively), spiders (8.3%), and stonefly nymphs (7.5%) (Anderson *et al*. 2002). In this population, there was a seasonal shift in the composition of the chick diet. First broods were provisioned a preponderance of midges, second broods were fed a greater proportion of damselfly and stonefly nymphs, while third broods received more adult beetles (Anderson *et al*. 2002). The exploitation of aquatic larval stages of insects, which is not likely to be common feature of all Tree Sparrows, suggests that this species is capable of making use of locally abundant food sources (Anderson *et al*. 2002).

Wintering requirements

Tree Sparrows remain near the breeding colony in the winter, rarely straying more than a few kilometres, although they may join with birds from neighbouring colonies in feeding flocks. Most birds feed in arable farmland, taking cereals (principally in the autumn) and weed seeds (see above for details), which can contribute up to 90% of the diet in the late winter (Keil 1973). Hancock and Wilson (2003) showed that the highest densities of Tree Sparrow were found in field boundaries and undersown cereal stubbles. Furthermore, Siriwardena *et al*. (2004) documented that this species was more abundant on winter feeding sites close to vegetative cover, and in areas with mixed farming.

Linnet *Cardeulis cannabina*

Linnets are widespread throughout England and Wales, although scarcer in upland areas. The range extends into southern Scotland, but further north Linnets are restricted to the coastal fringe (Gibbons *et al*. 1993). This predominance around the coastline is also exhibited in east and south England. Linnets are commonly associated with Gorse *Ulex* (Leguminosae), but are found in other habitats that provide dense habitat. Seventy percent of Linnets in the UK nest on farmland (Gregory & Baillie 1998).

Linnets declined by 41% in the UK between 1968 and 1995 (Siriwardena *et al.* 1998). This decline was actually concentrated between the mid-1970s and 1987, and there has been a slight increase since (Moorcroft & Wilson 2000). As a subsequence of this decline Linnet is on the red list of Birds of Conservation Concern (Gibbons *et al*. 1996) and a UK BAP Priority Species.

Breeding season requirements

Linnets breed semi-colonially, forming the largest nesting groups of any of the *Carduelis* species (Tast 1970), although they will breed in isolation (it is postulated that this may be caused by low levels of available nesting habitat, Frey 1989). Nests are located in hedgerows, dense shrub or isolated bushes. As Linnets nest colonially they do not defend territories but rather defend their mate to insure paternity (Drachmann, Komdeur & Boomsma 2000). Breeding birds feed communally in areas of abundant food, travelling up to 2 km from the nest site to feed. This wide-ranging foraging behaviour means that habitats in the immediate vicinity do not necessarily determine the location of nest sites.

Linnets are unusual amongst finches in that they feed almost entirely upon seeds – even nestling diet only contains a small proportion of aphids and a few small caterpillars (Wilson *et al*. 1997a). They also tend to avoid berries and fruits and rarely take tree seeds. Traditionally, the main food items of Linnets have been weed seeds, including those of bistorts and docks (Polygonaceae), chickweeds and mouse-ears (Caryophyllaceae), Brassicas such as charlock *Sinapis arvensis* and oilseed rape, a wide variety of composites (Compositae) such as dandelion *Taraxacum*, thistles *Cirsium*, groundsel *Senecio* and sow-thistles *Sonchus* and some grasses (Gramineae) (Wilson *et al*. 1997a). However, there have been temporal changes in the composition of the Linnet's diet in recent decades. In particular, oilseed rape was absent from Linnet diet in 1962-64 (Newton 1967), but currently forms a major component, with only dandelions and sow-thistles more important (Moorcroft *et al.* 1997). The current importance of oilseed rape in the Linnet's diet is illustrated by the fact that recent studies have demonstrated improved nestling growth rates, condition, and fledging success in nests proximate to rape fields (Moorcroft 2000; Bradbury *et al*. 2003). As many other weed species have declined in recent decades, the increase of oilseed rape as a crop has probably softened the impact of these declines on the Linnet population. In contrast, weeds of grassland have not declined to the same extent of those in arable farming systems; indeed, some species such as dandelions *Taraxacum*

(Compositae) have increased in abundance, as they are tolerant of both grassland "improvement" and heavy grazing pressure (Grime *et al*. 1988).

Wintering requirements

The winter distribution of Linnets in Britain is rather similar to that in the summer, although altitudinal migration means that they are largely absent from upland regions (Lack 1986). A proportion of the population migrates south to continental Europe to winter; although this has not been precisely quantified, Lack (1986) gives an estimate of half of the population emigrating. Most Linnets concentrate on arable farmland, although they are also to be found on waste ground and on coastal habitats such as saltmarshes. They gather in small flocks, although these can number up to 200 or even higher, and large roost gatherings are common (Newton 1972). Thick scrub such as hawthorn *Crataegus* (Rosaceae) or gorse *Ulex* (Leguminosae) is selected for roosting. Diet consists entirely of seeds during the non-breeding season, with grasses, thistles, dandelions and bistorts and docks being the most important components.

Wilson *et al*. (1996) found that Linnets showed a very strong preference for foraging in stubble fields in the winter, while Moorcroft *et al*. (2002) demonstrated that they select for stubble fields with high weed seed density. Linnets were rarely found in fields where the density of weed seeds important in their diet fell below $250m^{-2}$. In addition, within selected fields Linnets prefer to forage in areas of high seed density and with a greater proportion of bare earth (Moorcroft *et al*. 2002).

Goldfinch *Cardeulis carduelis*

The Goldfinch is a widespread bird, found throughout England and Wales and most of Scotland. The range has spread northward for several decades (Gibbons *et al*. 1993). Although Goldfinches are present in Britain throughout the year, the majority (maybe as high as 80%, Newton 1972) migrates south in September and October to winter in Belgium, France and Iberia.

Breeding season requirements

Goldfinches nest in a variety of lowland habitats, mainly those that are open with scattered shrubs or trees. Woodland edges, parkland and gardens are used, but the large part of the population is found breeding on farmland. Shrubs and trees are used for nesting; as nests are usually 4-10 m above the ground short, intensively managed hedges are not suitable for breeding in (Gibbons *et al*. 1993). Like other Cardueline finches, Goldfinches will nest in loose colonies.

The diet of adult Goldfinches is dominated by Compositae (see below), with few wild grasses or cultivated cereals. Therefore Goldfinches require sufficient weedy areas, either within crops, along margins or in other habitats such as rough ground or set-aside. These do not have to be in the immediate vicinity of the nest, as Goldfinches will range widely to forage (Newton 1972). Little is known of the diet of Goldfinch nestlings, but it is thought to contain invertebrates such as caterpillars, aphids (Aphidididae), small flies (e.g. Muscidae), ants (Formicidae), small beetles and their larvae (e.g. Curculionidae, Chrysomelidae, Coccinellidae, Elateridae) and parasitic wasps (e.g. Braconidae) as well as regurgitated seeds, presumably similar to those eaten by the parent birds (Wilson *et al*. 1997a).

Wintering requirements

As stated previously, most Goldfinches migrate south from Britain in the autumn, returning in April. However, birds remain throughout the range through the winter, with some withdrawal from higher ground (Lack 1986). As in the breeding season, Goldfinches are reliant on a diet of weed seeds, with a marked preference for Compositae when available. These include thistles *Cardius* and *Cirsium*, dandelions *Taraxacum*, groundsels and ragworts *Senecio*, Knapweeds *Centaurea* and burdocks *Arctium*. Thistles provide a third of the annual diet (Newton 1967). Later in the winter Goldfinches will also feed on the seeds of birches *Betula*, alders *Alnus* and Teasel *Dipsacus fullonum* as resources such as dandelions become depleted. This change in diet in the late winter, and the departure of the large part of the population, suggests that winter food resources may be limiting for Goldfinches in Britain (Lack 1986).

Greenfinch *Carduelis chloris*

Greenfinches are widespread and common, being absent only from treeless upland regions of Britain. Unlike the other finches described above, Greenfinches are chiefly resident in Britain, with a December population estimated to be as high as 5-6 million (Lack 1986). Numbers are believed to have been relatively stable since the mid 1960s (Gibbons *et al*. 1993).

Breeding season requirements

Although nesting in trees and in part reliant on their seeds as food, Greenfinches do not nest in densely wooded areas but instead prefer a mosaic of habitats including tall trees. Therefore they are found in a wide variety of habitats but usually those with a mix of trees and shrubs and open areas; farmland, parks and suburban gardens are favoured habitats. Greenfinches have adapted well to the influence of man both on agricultural land and in suburban and urban areas (Newton 1972).

Nests are placed in small trees or large shrubs. Unlike some other Cardueline finches, Greenfinches do not forage in flocks in the breeding season, and usually do not forage long distances away from the nest.

The large bill of the Greenfinch means it is able to take a wide variety of seed types. The most important dietary items are probably tree seeds such as from spruce *Picea* (Pinaceae) and elm *Ulnus* (Ulmaceae). Also taken are the seeds of weeds such as Chenopodiaceae, dicks and bistorts (Polygonaceae), chickweeds Stellaria (Caryophyllaceae), wild and cultivated Brassicas (Cruciferae), groundsel *Senecio,* burdocks *Arctium* and Dandelions *Taraxacum* (Compositae).

Nestling diet is similar to that of parents, but contains a slightly higher incidence of invertebrates, especially aphids and caterpillars (Wilson *et al*. 1997). There is some evidence that oilseed rape may have become more important for brood rearing, possibly compensating for declines in weed seeds and invertebrates (R. Bradbury, pers. comm.).

Wintering requirements

The feeding habitats of Greenfinches become more generalised in the winter, with birds staying in the breeding habitats but also dispersing to rough and open ground along the coast, and on arable farmland (Lack 1986). There is a slight retreat from upland regions, and a low level of emigration.

In wood and parkland, Greenfinch feed on yew *Taxas buccata* (Taxaceae), hornbeam *Carpinus betulus* (Corylaceae), whitebeam *Sorbus*, rose *Rosa* and bramble *Rubus* (Rosaceae). In arable land, Greenfinches consume a wide variety of weed seeds, but particularly, charlock *Sinapsis arvensis* (Cruciferae) and Persicaria *Polygonum* (Polygonaceae) are important. Wilson *et al*. (1996) showed that in agricultural habitats, Greenfinch show a strong preference for feeding on over-wintered stubbles.

Greenfinches have shown an increasing use of bird tables (Lack 1992). This reliance on peanuts and other provided foods such as sunflower seeds are probably responsible for maintaining the population at its current level, especially in late winter and early spring when supplies of naturally occurring seeds become depleted. Greenfinches have become less abundant on farmland, where favoured weed species have declined, instead wintering around towns and villages.

Reed Bunting *Emberiza schoeniclus*

Reed Buntings are widespread and resident through out Britain although, like many farmland bird species considered in this review, they are absent from upland areas. In recent decades there has been a slight contraction of range, predominantly in the north and west (Gibbons *et al*. 1993). Reed Buntings increased in numbers between 1963 and 1975, expanding into less preferred farmland habitats as numbers increased. However, this increase was followed by a steep decline in numbers between 1975 and 1983. During this period Reed Buntings declined by 58% on farmland and by 66% along linear waterways (Peach *et al*. 1999) which led to Reed Bunting being placed on the red list of Birds of Conservation Concern (Gibbons *et al*. 1996) and a UK BAP Priority Species. Population levels have remained relatively stable since this decline.

Breeding season requirements

Reed Buntings on farmland are typically associated with wet margin habitats. Brickle and Peach (2004) found that rank grassland and herbaceous vegetation, much of which adjoined wetland features, was the dominant habitat type (30%) within 100m of bunting nests, whereas farmed habitats, such as set-aside and cereals, were less important constituents. In a Polish Reed Bunting population, reeds (22.2%) were the principle habitat type in breeding territories, followed by herbaceous vegetation (12.7%) and meadows (8.8%; Surmacki 2004). Nests are generally placed close to ground level (mean height 25 cm; Brickle and Peach 2004), particularly in dense, herbaceous vegetation, which affords a greater degree of concealment from predators (Brickle and Peach 2004; Surmacki 2004). Buntings rarely locate their nests in reeds, which instead serve as song-posts for territorial establishment and defence (Gordon 1972; Surmacki 2004). Where wetland features on agricultural farmland are scarce, oilseed rape appears to be suitable alternative habitat for Reed Buntings. Gruar *et al*. (2006) demonstrated that the density of bunting in oilseed rape fields was 4.3 times greater than the densities on wheat, barley and set-aside fields. It was speculated that rape might permit Reed Bunting to breed on arable farmland that would otherwise be unsuitable because of a dearth of wetland features (Gruar *et al*. 2006).

Reed Buntings principally forage in close proximity to the nest; Brickle and Peach (2004) showed that 87% of foraging sorties were within 100m from the nest, whereas only 2% were in excess of 200m. Rank and emergent vegetation is a favoured habitat type in which to forage during the breeding season, presumably because these habitats are characterised by greater food abundance (Brickle and Peach 2004). The diet during the breeding season consists primarily of invertebrates (Prys-Jones 1977), although both adults and offspring will consume a variable amount of seeds, particularly those of grasses (Brickle and Peach 2004). Precisely which prey is taken varies through the breeding season. Springtails (Collembola) and midges *Chironomidae* (Diptera) are important in adult diet early in the spring. In April and May caterpillars (Lepidoptera) (foraged for in hedges and trees) are the most important component, and by June-July spiders (Araneae) and dragonflies and damselflies (Odonata). Also taken are craneflies (Tipulidae), weevils (Curculionidae), horse flies (Tabanidae), mayflies (Ephemeroptera), sawfly larvae (Symphyta: Tenthredinidae) and Orthoptera (Cramp & Perrins 1994, Wilson *et al*. 1997a). Brickle and Peach (2004) found that caterpillars (Lepidoptera and Symphyta larvae – 41%) comprised the bulk of provisioned insect food to chicks, followed by spiders (Araneae – 29%), beetles (Coleoptera – c. 15%) and flies (Diptera – 12%)

Wintering requirements

There is little emigration from Britain during the winter, with less than 1% of birds leaving the country (Prys-Jones 1984). Aside from a withdrawal from more upland regions, Reed Buntings are found in most farmland areas during the winter, although they are scarce in some regions such as mid-East Anglia and the south-west (Lack 1986). They are found widely spread over farmland in small flocks, although they congregate in evening roosts in marshy areas such as reedbeds. Most birds do not move far from the breeding site in the winter (Prys-Jones 1984) although movements of 10-20 km are quite common (Fennell & Stone 1976).

In winter, Reed Buntings feed mainly on the seeds of grasses and herbs, often taken from or near the ground. A diverse range of seeds are taken, including goosefoots (Chenopodiaceae), amaranths (Amaranthaceae), chickweeds and mouse-ears (Carophyllaceae), crucifers (Cruciferae), lupins *Lupinus* (Leguminosae) and the seeds of wild grasses such as meadow-grass *Poa*, millet *Setaria*, fescues *Festuca*, rye-grass *Lolium* and cockspur *Echinochloa*. Grass seeds are particularly important, with Prys-Jones (1977) estimated that 67.5% of all seeds taken were grass seeds. Unlike other buntings, cereal seeds are relatively unimportant to Reed Buntings, although they can form a larger proportion of the diet in the late winter when other seed stocks have been diminished. A study of lowland farms in central England showed that Reed Buntings preferentially selected intensive barley stubbles on which to forage during the winter, because these habitats were associated with greater densities of key dietary seeds, and also there was increased areas of bare soil, which apparently allowed more effective feeding (Moorcroft *et al*. 2002). Buntings were rarely found on stubble fields that held seed densities of below 250 seeds/m^2 (Moorcroft *et al*. 2002). In Poland, however, wintering buntings preferred to forage in densely weeded fields, while cereal stubbles were characterised by a relatively low abundance of birds (Orlowski 2005). Invertebrates are also taken during the non-breeding season, including spiders (Araneae), springtails (Colembola), Hemiptera, Diptera larvae and beetles, but they form only a small component of the diet (5% of dietary items, Cramp & Perrins 1994).

There is strong evidence that first-year (and, to a lesser extent, adult) survival decreased during the late 1970s and the 1980s, the time during which the British population was declining. These declines in over-winter survival were sufficiently large to have caused the population decline and, given that nesting success was relatively high during this period, are likely to have done so. However, a loss of breeding habitat and a recent reduction in breeding performance may also have influenced numbers (Peach *et al*. 1999). It is likely that declines in this period were due to loss of winter food resources, especially weed-rich stubbles, the preferred feeding habitat (Wilson *et al.* 1996) that were lost at a high rate during the period of Reed Bunting decline.

Yellowhammer *Emberiza citrinella*

Yellowhammers are widely distributed across lowland Britain, being absent only from the Pennines and north and west Scotland, as well as a few pockets in Wales. However, although well distributed, there is marked variation in abundance with greater densities being found in the Midlands and eastern Britain. A slight contraction in range in the western part of Britain has been detected in recent years (Gibbons e*t al*. 1993). This contraction in range is slight compared to the fall in abundance displayed in recent years: Yellowhammers are unique amongst British farmland birds in that they did not start to decline until the late 1980s. However, since that date the CBC (Common Bird Census) population index for Yellowhammers has declined rapidly (Siriwardena *et al*. 1998). Yellowhammers are likely to be placed on the red list of Birds of Conservation Concern in the near future. British Yellowhammers are, for the large part, sedentary. Therefore, unlike some of the other species considered in this review, they require both suitable breeding and non-breeding resources to be present in the same area.

Breeding season requirements

Yellowhammers nest along field boundaries, either on or near the ground in ditches or uncropped margins, or in hedges or isolated shrubs (Kyrkos 1997). Nest height increases through the breeding season, as birds tend to shift from breeding in margins to breeding in hedges themselves (Bradbury & Stoate 2000). Therefore, they select boundaries with hedges, ditches and wide uncropped field margins (Bradbury *et al.* 2000). Even if not used for nesting, hedges, shrubs and hedgerow trees are required as singing posts, perches for vigilance and cover from predators (Biber 1993). The adjoining crops are also important in determining Yellowhammer presence, with birds tending to avoid boundaries adjoining grassland. Kyrkos *et al*. (1998) found that Yellowhammer density decreased with increasing proportion of farmland under grassland. It may be that “modern” improved grassland has neither the weed density required by adult Yellowhammer or sufficient invertebrate prey for birds feeding nestlings. The dense sward structure of highly fertilized leys may also reduce access to invertebrate prey (Perkins *et al*. 2000). Finally, a recent study demonstrated that winter set-aside had a strong influence on the distribution of Yellowhammers during the breeding season (Whittingham *et al*. 2005). The authors invoked the relatively sedentary nature of this species to explain why breeding distribution should necessarily be linked to availability of suitable wintering habitat (Whittingham *et al*. 2005).

Stoate & Szczur (1997) found that Yellowhammer showed a distinct preference for foraging in some habitats, and this habitat choice changed through the breeding season. In the early part of the breeding season (early June) rape and beans were the most favoured habitat, followed by tracks/set-aside and then barley. Pasture/woodland was poorly favoured, wheat even less so. However, later in the breeding season (late June – July) barley and then wheat were the most favoured habitats, followed by field boundary, rape/beans. Douglas *et al*. (in prep) also demonstrated a seasonal shift in foraging habitat selection; early in the breeding season, field margins were used heavily, but by late summer, there had been a marked increase in the relative use of cereal crops. Field margins consistently harboured the greatest abundance of important chick food items, but Douglas *et al* (in prep) suggested that pronounced growth of field margin vegetation limited access to these food resources, thus prompting the habitat switch. Similarly, Morris *et al*. (2001) also found that Yellowhammers showed a consistent preference for boundary features and winter barley, whereas stubbles and cultivated grass fields being avoided. At a smaller spatial scale, Yellowhammers foraged preferentially in patches with short, sparse vegetation and more bare earth than random non-foraged patches (Douglas *et al*. in prep). In cereals, specifically, foraging individuals favoured tractor tramlines, presumably because these afforded greater access to the soil (Douglas *et al*. in prep). Nearly all foraging is within about 300 m of the nest.

Adult diet is principally granivorous. Cereal grain and the seeds of wild grasses are preferred. These include meadow-grass *Poa*, rye grass *Lolium*, fescues *Festuca* and couch *Elymus* (Graminaeae). Seeds of other taxa, including composites (Compositae), bistorts, docks and sorrels (Polygonaceae) and chickweeds (Caryophyllaceae) form a smaller proportion of diet (Cramp & Perrins 1994, Wilson *et al*. 1997a). Almost all of this food is gained from foraging on the ground.

Stoate *et al*. (1998) found cereal husks in a high proportion of nestling faecal samples from Leicestershire, but also found invertebrate remains in every faeces. Invertebrate prey includes spiders (Araneae), Coleoptera including ground beetles (Carabidae) and weevils (Curculinonidae), Lepidoptera (both adults and larvae) and Diptera such as craneflies (Tipulidae) and st mark's-fly (Bibionidae) (Cramp & Perrins 1994, Stoate *et al.* 1998, Moreby & Stoate 2001). The importance of cereal grain (unripe) is probably much greater in summers of cold or wet weather when insect availability may be low.

Wintering requirements

A study of winter habitat use by Yellowhammers in Leicestershire by Stoate & Szczur (1997) found that both oil-seed rape and cereal crops were avoided in the winter. Cereal-based "wild-bird cover", planted with wheat and triticale, was the most-preferred habitat in the early winter, but less so in the late winter. Gamebird feeding sites were used throughout the winter. Another study, in Oxfordshire (Wilson *et al*. 1996), found that grass was used less than expected, as were a number of crops such as broad-leaved crops, intensive winter wheat fields and bare tillage. The only habitat type that a clear preference was displayed for was winter stubble. The winter diet of Yellowhammer consists of weed seeds as listed above, and cereal grain. Radiotelemetry studies and intensive winter observation work suggest that Yellowhammers are fairly sedentary during the winter period, birds rarely travelling more than 1 km between winter food sources (Calladine *et al*. 2006; Siriwardena *et al*. 2006).

Corn Bunting *Miliaria calandra*

Corn Buntings are largely restricted to farmland in Britain, with a strong association with cereal farming. They also have strongholds in other habitats such as downland pasture and Hebridean machair. Declines in the British population were noted as long ago as 1920s, but have gathered pace in more recent decades (Gibbons *et al*. 1993). However, following a decline during the agricultural depression between the two world wars, populations and range in the West Midlands increased with the area of spring barley in the 1960s and 1970s (Harrison *et al*. 1982), but has since declined with losses in spring barley and rotational, short term leys (West Midland Bird Reports). The current UK population is estimated at 20,000 territories (Corn Buntings are polygynous, (Ryves & Ryves 1934)) (Donald & Evans 1995). The range has contracted massively, particularly in the west and north of the range, with some additional enlarging "gaps" in the east.

Breeding season requirements

Corn Buntings are birds of open farmland and grassland. In Britain, several studies have sought to describe the broad habitat preferences of this species, but to date, few generalisations can be made. Corn Buntings are often associated with areas of tillage, but the type of tillage vary according to specific regional populations. For example, winter barley was favoured by Corn Buntings in Lincolnshire (Aebischer and Ward 1997), while spring barley was positively selected in southern England (Gillings and Watts 1997). Brickle and Harper (2000) demonstrated that spring-sown barley and winter wheat were both preferred in a West Sussex population of Corn Bunting, although grass margins were the most strongly selected habitat feature. In contrast, some studies have found no apparent selection for (Mason and MacDonald 2000) or even an avoidance of cultivated crops (Diaz and Tellaría 1997). Furthermore, in southern England, grassland was a favoured habitat type (Aebischer and Ward 1997; Wakeham-Dawson 1997), while it was largely avoided in South Uist (Hartley and Shepherd 1997). Corn Bunting populations in other European countries appear to show different further contrasting patterns of habitat selection, for example, preferring set-aside in north-east Germany (Fischer and Schöps 1997), uncultivated habitats in Iberia (Diaz and Tellaría 1997), and wet grasslands and marshes in Switzerland and Slovenia (Hegelbach and Ziswiler 1979; Tome 2002). Other habitat features that Corn Buntings appear to favour include ditches, grassy tracks and elevated singing perches (isolated trees, bushes, posts etc; Eislöffel 1997; Mason and MacDonald 2000).

Corn Bunting nests are often situated on the ground or slightly above ground level (up to 15 cm, Gillings and Watts 1997), often in tall 'grassy' habitats: standing cereals, ungrazed grass, field margins, or set-aside. Hartley and Shepherd (1997) found that nests in North Uist were significantly more likely to be located at the base of Hogweed *Heracleum sphondylium* than other species of plants. Compared to other avian granivores breeding in farmland, the onset of reproduction in the Corn Bunting is relatively late in the season. For example, the median first egg date of breeding attempts in the South Downs was 6th June, with some attempts being initiated as late as the end of July (Brickle and Harper 2002). This late breeding may make Corn Buntings susceptible to nest loss or fledgling death during harvesting (Crick *et al*. 1991). Brickle and Harper (2002) found that although predation accounted for the majority of nest failures in their Corn Bunting study population, there was seasonal decline in the nest survival rate during incubation, which was largely due to increased losses through farming operations. Furthermore, Brickle and Harper (2002) also speculated that harvesting of cereal crops may reduce the availability of suitable breeding habitat late in the season, thus curtailing the length of the breeding season, and preventing double-brooding. A reduction in fecundity via these mechanisms may elucidate the collapse of the Corn Bunting population in Britain and more widely across Europe (Donald 1997; Brickle and Harper 2002).

The diet of Corn Bunting chicks is mainly insects, although unripe grain is fed to them (Watson 1992, Gillings & Watts 1997, Brickle & Harper 1999). Brickle and Harper (1999) found that sawfly (Symphyta) and moth (Lepidoptera) larvae, grasshoppers (Orthoptera), spider (Araneae) and carabid beetles (Carabidae) were the most important food items for nestling Corn Buntings. Flies (Diptera) may be important in areas with damp or aquatic habitats (Hartley & Quicke 1994), although Corn

Buntings are traditionally associated with free-draining soils. Adult diet in the breeding season is similar to that fed to chicks (Wilson *et al*. 1997a). Corn Buntings do most of their foraging within crop fields, although field margins and road verges are also used, and at all seasons grain may be foraged upon at stock feeding trough, spread slurry, dung, bales and stacks and on seeds spread for stock-feeding (Watson & Rae 1997). Brickle *et al*. 2000 found that Corn Buntings in West Sussex preferentially foraged in grassy field margins, spring-sown barley, unintensified grass and set-aside, where invertebrate chick food was more abundant.

Finally, several authors have commented on the seemingly contrasting habitat preferences of the Corn Bunting in Britain and Europe (Donald and Evans 1995; Harper 1997; Mason and MacDonald 2000). For example, Mason and MacDonald (2000) accounted for these conflicting patterns by suggesting that this species adapts to local conditions in their summer nesting habitats. An alternative, perhaps more worrying interpretation of these patterns is that, especially in the Britain where the species is increasingly threatened, all populations are nesting in non-optimal habitats, and different apparent habitat preferences simply reflect random habitat features of areas in which local populations have managed to hang on the longest. However, this seems rather unlikely as the habitat preferences are in line with the known ecological requirements of the species and of similar species

Wintering requirements

Historically, Corn Buntings were abundant around stack yards and threshing yards during the winter, so it appears that spilt grain was once an important winter food (Donald *et al*. 1994). With cleaner and more efficient farming practices such food sources are no longer available. As with other buntings, seeds form the majority of the winter diet of Corn Buntings. They differ from other buntings in that the grain of cultivated cereals is by far the most important component of diet, (Wilson *et al*. 1997a), although the seeds of grasses and other plants may be important, especially when grain stubble supplies dwindle (R. Setchfield pers. comm.). Winter stubbles are the source of this preferred food. Donald & Evans (1994) found that 60% of Corn Buntings fed on winter stubbles, which were the only field type for which a consistent preference was detected. Weedy stubbles were preferred to clean ones. Winter cereals were avoided in all land-use types, and while grassland was used in some cases (unimproved and semi-improved grassland are used roughly in proportion to their availability), improved grassland was always avoided. Moorcroft *et al*. (2002) demonstrated the Corn Buntings were more often found foraging on intensive barley stubbles, rather than those of intensive or organic wheat. Furthermore, they also were positively associated with the percentage of dietary weeds and the area of bare earth (Moorcroft *et al*. 2002).

Watson & Rae (1997) found that favoured stubble fields in north-east Scotland were those with patches of tall vegetation remaining. Grass pasture was sometimes used, autumn-sown cereals seldom so. As with many small passerines, Corn Buntings often feed close to cover (Robinson & Sutherland 1997), so hedgerow removal may have resulted in higher predation risk for birds during the winter period.

Corn Buntings gather in winter roosts, using reed-beds, gorse patches and scrub. In southern England roosts of 300-500 were not uncommon, which Lack (1986) suggested may be evidence of a lack of suitable roost sites, possibly due to recent habitat loss.

		Kestrel	Grey Partridge	Lapwing	Stock Dove	Woodpigeon	Turtle Dove	Barn Owl	Skylark	Yellow Wagtail	Whitethroat	Jackdaw	Rook	Starling	Tree Sparrow	Linnet	Goldfinch	Greenfinch	Reed Bunting	Yellowhammer	Corn Bunting*
Nesting requirement	Buildings	2			2			4				2		4	2						
	Tree holes	4			4			4				4		4	4						
	Trees					4	2						4		2		4	4			
	Shrubs					2	4				2					2	4	4	2	2	
	Hedges					2	4				4				1	4	2	2	2	4	
	Margins/rank grass and herbs		4	2						2	4								4	4	4
	Cereal crops		2	4					4	4											4
	Broad-leaved crops			4					2	4									4		2
	Grassland		2	4					4	4											2
Foraging habitat	Woodland				1	1															
	Scrubland				1	1					3				3			1	2	1	
	Parks/gardens				1	1						1		2	2			1			
	Hedges										3				3			1	2		
	Margins/rank grass	3	2		1		2	4	2	2	3	2		2	1	2	1	1	2	4	4
	Damp/aquatic habitats			4				2		4					4				4	1	1
	Cereal		4	2	2	2	1		4	2			1		1	2			2	4	4
	Broad-leaved crops			2	3	4	4		2	2			1		1	4			4	2	1
	Set-aside: rotational	1	4	2	1	4	1	1	3	1		1	1	1	1	3	3	1	2	2	1
	Set-aside: non-rotational	3	4	1	1	4	1	3	4	1		1	1	1	1	3	3	1	1	2	4
	Grassland	2	2	4				2	2	2		4	4	4		2	2				2
Food	Tree seeds/fruit					2					2	2						2			
	Grain				4	4	4					2	2		2			2		2	2
	Weed seeds		2		4	4	4								2	4	4	4		2	
	Rape				2	2	2									4		4	2		
	Foliage		2		2																
	Soil invertebrates	2	2	4	2	2	2		2			2	4	4	2						
	Other invertebrates	2	4	2	2	2	2		4	4	4	4	2	2	4		2	2	4	4	4
	Vertebrates	4						4				2	2								

Table A1.1 Main nesting, foraging habitat and food requirements of the species in the Farmland Bird Index during the breeding season. Black squares indicate resources considered to be of major importance; grey squares those of secondary importance or for which selection was not consistent. 4 = important resource, documented in published study. 3 = important resource, expert opinion. 2 = secondary resource, documented in published study. 1 = secondary resource, expert opinion.

* in some areas (e.g. NE Scotland), grassland is an important nesting and foraging habitat for corn bunting

		Kestrel	Grey Partridge	Lapwing	Stock Dove	Woodpigeon	Barn Owl	Skylark	Jackdaw	Rook	Starling	Tree Sparrow	Linnet	Goldfinch	Greenfinch	Reed Bunting	Yellowhammer	Corn Bunting
Foraging habitat	Woodland														1			
	Scrubland														1			
	Parks/gardens											1			3	1		
	Hedges		1									1			1	1		
	Margins/rank grass	3	1		1		4	1	1			1	1	1	1	1	1	1
	Damp/aquatic habitats						2									1		
	Cereal			4	2	2		2	2	2	1							2
	Broad-leaved crops		2	2	1	3		2	2	2	1	3				1		2
	Set-aside: rotational	1	2		1	4	2	4	4		1	2	4	1	1	1	4	
	Set-aside: non-rotational	3	4		1	1	3	4			1		4	4	1	1	4	
	Stubble (non-set-aside or unspecified)		4	2	1	4		4			1	2	4	4	1	1	4	2
	Grassland	3	2	4			2		2	2	4							2
Food	Tree seeds/fruit					2			2	2	2			4	2			
	Grain		4		4	4		2	4	4	4	4			2	2	4	4
	Weed seeds		4		2	4		4	2	2	2	4	4	4	4	4	2	2
	Rape				4	2						2						
	Foliage		2		2	2		2										
	Soil invertebrates	2		4				2	2	4	4							
	Other invertebrates	2		2				2	2	2	2					2	2	2
	Vertebrates	4					4		2	2								

Table A1.2 Main foraging habitat and food requirements of the species in the Farmland Bird Index during the non-breeding season. Black squares indicate resources considered to be of major importance; grey squares those of secondary importance or for which selection was not consistent. 4 = important resource, documented in published study. 3 = important resource, expert opinion. 2 = secondary resource, documented in published study. 1 = secondary resource, expert opinion.

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APPENDIX 2 REVIEW OF THE EFFECTS OF ENTRY LEVEL STEWARDSHIP AGRI-ENVIRONMENT OPTIONS ON FARMLAND BIRDS

INTRODUCTION

Agriculture in Britain, and more widely in Europe, witnessed profound changes in the latter half of the 20th century, characterised by the adoption of increasingly intensive management practices. Coincident with, and precipitated by, this period of agricultural intensification, biodiversity associated with farmland has experienced widespread decreases and impoverishment. In particular, the decline of farmland birds is well documented. For example, Siriwardena *et al.* (1998) demonstrated that of 13 farmland specialists in Britain, 11 declined between 1968-1995, whereas only two species increased in abundance during this same period. Broadly similar patterns of decline have been confirmed in other taxa associated with farmland, including mammals (Flowerdew 1997), arthropods, and flowering plants (Sotherton *et al.* 2000).

The primary policy instrument that European governments have to combat the erosion of biodiversity in agricultural regions are agri-environment schemes. In these, farmers receive payments, reimbursing profits forgone, to follow prescribed management practices that were developed with environmental and ecological benefits at their core (Evans *et al.* 2002). Following on from the Environmentally Sensitive Areas (ESA) and Countryside Stewardship (CS) schemes, the principal agri-environment programmes in England are the Entry Level Stewardship (ELS) and Higher Level Stewardship (HLS) schemes (reviewed in Grice *et al.* 2007). These new schemes, initially launched in 2005, adopt a two-tier approach to the preservation of farmland biodiversity (Grice *et al.* 2007). ELS is targeted at a wide audience, with the objective of implementing simple, practical management prescriptions that fit with conventional farming systems, yet that deliver measurable environmental and biodiversity benefits (Grice *et al.* 2007). HLS, on the other hand, involves the implementation of more demanding, tailored management options, designed to meet specific biodiversity requirements of particular circumstances (Grice *et al.* 2007). Through the adoption of such ‘broad and shallow’ agri-environment schemes, it is possible to cater for the needs of both declining, yet still relatively common farmland species, and more threatened range-restricted species.

Agri-environment schemes in Europe have been the subject of recent criticism, because despite the vast amounts of capital devoted by the EU countries to these schemes, few have been rigorously monitored and so very little is known about their efficacy (Kleijn and Sutherland 2003). Where monitoring has been carried out, delivery of biodiversity has been disappointing (Kleijn and Sutherland 2003). The English agri-environment schemes, however, are one exception to this rule; these have been developed through an iterative process of design, trial and revision (Evans *et al.* 2002). This current review forms an integral part of this revision process. It is the purpose of this review to synthesise for each of the agri-environment options within ELS the documented benefits of these for farmland birds, with a particular focus on the 19 Farmland Bird Index (FaBI) species. The review is structured such that it considers the breeding season benefits (nesting and foraging) and winter season benefits (foraging only) afforded by each prescription independently. We assess the existing evidence that individual prescriptions provide measurable benefits for farmland birds, and consider whether they may be adjusted, through modifications to establishment or management, to better improve their delivery for these species.

ENTRY LEVEL STEWARDSHIP PRESCRIPTIONS

Options for Boundary Features

EB1 – Hedgerow management (on both sides of hedge)
EB2 – Hedgerow management (on one side of hedge)
EB3 – Enhanced hedgerow management

With the intensification of agriculture in recent decades, semi-natural habitat has become increasingly rare in the farming landscape, and hedgerows now constitute one of the most important surviving elements of this habitat type. For an array of bird species, hedgerows are a crucial component of the agricultural environment, providing appropriate nesting and roosting sites, foraging habitat, and shelter from both predators and inclement weather. The agri-environment options described here attempt to manage hedgerows in such a way as to afford maximal benefits for birds and other biodiversity. These options place restrictions on the frequency and period during which hedges can be cut, impose a minimum hedge height of 1.5 m, and limit the extent of cultivation or pesticide input that can be applied within 2m of the centre of the hedgerow (Anon 2005).

Breeding season resources

Several studies have evaluated how the structural characteristics of hedges influence their associated bird assemblages (Green *et al.* 1994; Parish *et al.* 1994; 1995; MacDonald *et al.* 1995), and these studies permit an assessment of the manner in which farmland birds might respond to hedgerow management. The general pattern that emerges from these studies is that bird species richness and abundance increases as a function of greater hedge size (e.g. height and width), and with the presence of more mature trees (reviewed in Hinsley and Bellamy 2000). However, it should be noted that the suite of species considered by these studies includes a number of birds characteristic of woodland habitats, and consequently, these preferences may not be representative of farmland specialists. For example, Green *et al.* (1994) demonstrated that the Whitethroat, Linnet and Yellowhammer all exhibited a preference for short hedges with relatively few trees, while other species, such as Skylark, Corn Bunting and Yellowhammer, often show a strong aversion to hedgerows. Hinsley and Bellamy (2000) suggested that, in general, birds select hedgerows that most closely resemble the structure of their typical non-hedgerow breeding habitats. Thus, to maximise both the diversity and density of birds in farmland, optimal hedgerow management should promote the establishment of a range of hedgerow structures and compositions, catering for the habitat requirements of the full spectrum of specialist and generalist farmland birds (Green *et al.* 1994; Hinsley and Bellamy 2000; Chamberlain *et al.* 2001; Fuller *et al.* 2001).

For certain species, it is not so much the structural characteristics of the hedge itself that determine its attractiveness as a breeding habitat, but features of the herbaceous vegetation at its base. For example, controlling for the length of hedgerow available in the landscape, Rands (1986) demonstrated that the amount of dead grass present at the base of a hedge was the strongest predictor of Grey Partridge breeding density. The finding of another study, that the quantity of dead grass reduced the likelihood of a nest being depredated, strongly implies that such vegetation affords the eggs, and presumably also the incubating female, some concealment from predators (Rands 1982). Rands (1987) suggested that the optimal form of hedgerow management for Grey Partridge was biennial trimming, because this was associated with the most pronounced quantities of protective herbaceous vegetation, whereas unmanaged and grazed hedges were inappropriate for this species, because the base vegetation is shaded out or consuming by livestock respectively. Similarly, Stoate and Szczur (1994) posited that hedgerows lacking extensive herbaceous vegetation at their bases represent less suitable breeding habitats for Yellowhammer and Whitethroat.

Hedgerow management conducted under environmental stewardship options will not only affect the suitability of hedges via modifying their structure and composition, but will also influence the abundance of food resources offered by the hedge. Maudsley (2000) reviewed the scientific literature regarding the effects of hedgerow management on its dependent invertebrate community. The author concluded that the repercussions of frequent trimming on hedgerow invertebrates are complex and inconsistent, often varying according to particular taxa. Some insect groups, including Hymenoptera and Diptera, were negatively affected by regular cutting, while other herbivorous taxa were more abundant on annually-cut than unmanaged hedgerows (Maudsley 2000). Therefore, whether the hedge trimming restrictions imposed under ELS provide farmland birds with an increase in invertebrate prey remains to be demonstrated, and it is likely to depend on the relative importance of beneficially and adversely affected invertebrate taxa in a species diet. The author also suggested that the application of herbicides, either directly or indirectly via drift from adjacent field operations, will detrimentally impact the diversity and abundance of invertebrates associated with the hedge-bottom

(Maudsley 2000). Therefore, placing restrictions on pesticide application within a 2 m buffer zone of the centre of the hedgerow centre is liable to be advantageous for farmland birds, ensuring the retention of an abundant invertebrate prey assemblage. Finally, less is known about the manner in which the hedgerow management prescribed under these agri-environment options will influence bird plant-food availability.

Winter season resources

Hedgerows can be an important source of food for farmland birds during the winter, with shrubs such as Hawthorn *Crataegus monogyna*, Blackthorn *Prunus spinosa*, and Dog Rose *Rosa canina* providing an abundance of berries. Research has demonstrated, however, that different hedgerow management practices can markedly influence the size of the subsequent berry crop. Specifically, Croxton and Sparks (2002) showed that the yield of berries from annually cut hedges was poor, but as the intervening period between cuts increased in duration, the yield of berries increased. Unmanaged hedges yielded a berry crop that was 50 times greater than that of annually cut hedges (Croxton and Sparks 2002). It was suggested that cutting hedges on a three-year cycle would have many benefits; the cuts are often enough to maintain a well-managed appearance, but the reduced cutting frequency would have considerable wildlife benefits, particularly in terms of the increased berry yield for birds during winter (Croxton and Sparks 2002).

Conclusions and Recommendations

The use of hedgerows by farmland birds has been the focus of much research interest in Britain, and this literature has spawned a number of management recommendations that aim to improve the quality of these habitat features for birds. These recommendations have been used to underpin the development of the hedgerow agri-environment options, thus maximising the benefits hedges are likely to afford to a range of species. However, we lack definitive proof of the benefits afforded by hedgerow management techniques, because there has not been an explicit experimental study of the effects of practices on the territory distribution, foraging habitat selection, and reproductive success of characteristic hedgerow species. An investigation of this type would confirm the extent to which the predicted benefits highlighted by habitat selection studies are actually realised by hedgerow management. There are several other recommendations that can be advanced to improved the delivery of hedgerow management for farmland birds. Firstly, the EB1 and EB2 prescriptions stipulate that hedgerows cannot be cut between the 1st March and 31st July to prevent the disturbance of nesting birds. However, the nesting season of many species extends into August, which leaves still leaves the possibility of disruption. Although covered by the enhanced hedge management option, ideally all prescriptions should include the extended restricted cutting period of 1st March to 31st August. Secondly, these options make allowances for hedges that require to be cut frequently for the purposes of public safety e.g. those bordering roads. Instead of paying farmers for these hedges, it may be advisable to exclude such hedges from being incorporated into agreements. Thirdly, these options may also benefit from increased targeting of the habitat needs of particular species. That is, in the remaining strongholds of particular restricted-range or declining birds (e.g. Corn Bunting), it may be appropriate to manage hedgerows in such a way as to cater for the requirements of individual species, or groups of species (Hinsley and Bellamy 2000).

EB6 – Ditch management
EB7 – Half ditch management

Drainage ditches are an important diversifying habitat feature in agricultural landscapes, providing otherwise rare aquatic habitats, which are keenly exploited by farmland birds and other wildlife. These agri-environment prescriptions encourage the sensitive management of ditches for the benefit of wildlife by restricting the use of fertilisers and pesticides within the vicinity of them. Furthermore, there are restrictions on the frequency and period during which bankside vegetation can be cut, and ditches cleaned to minimise the extent of disturbance to the associated biodiversity.

Breeding season resources

Ditches offer important nesting opportunities for an array of farmland birds. For example, Bradbury *et al*. (2000) showed that the territory density of Yellowhammers was positively correlated with the presence of ditches on lowland arable farmland in England. This association reflects the Yellowhammer's preference for nesting in the herbaceous vegetation of ditch banks (Bradbury *et al*. 2000). Interestingly, Bradbury *et al*. (2000) also noted a seasonal shift in the height of this species' nests, which is indicative of the fact that early in the breeding season most nests are located on ditch banks, but as the season advanced, nests are increasingly sited in hedges. Stoate and Szczur (2001) similarly demonstrated that Yellowhammer settlement decisions were dictated in part by the presence of a ditch, but they also found that nests constructed on vegetated ditch banks were significantly more productive than those in hedges. Furthermore, where rank, emergent vegetation is permitted to develop at the margins of ditches, these provide suitable nesting habitat for several other farmland birds. Both Mason and MacDonald (2000) and Orłowski (2005) recorded Reed Bunting nesting along the fringes of ditches in their respective study sites, while Surmacki (2005) noted that three *Acrocephalus* warblers, the Sedge Warbler *A. schoenobaenus*, Reed Warbler *A. scirpaceus* and Marsh Warbler *A. palustris*, utilised drainage ditches as nesting habitat in an intensively farmed region of Poland.

For other species of farmland bird, the principle benefits yielded by ditches are as foraging habitats. For example, Peach *et al*. (2004) radiotracked Song Thrushes in a declining arable population, and showed that of fine-scale habitat features, the strongest predictor of fix density was the presence of wet ditches with hedges. The authors suggested that wet ditches were attractive to this species, because the presence of permanent water increased the soil's penetrability, thereby facilitating greater access to the species' primary prey, earthworms (Peach *et al*. 2004). Furthermore, Mason and MacDonald (2000) demonstrated that consistently occupied Corn Bunting territories in Essex were more likely to comprise water-filled ditches than those territories occupied only occasionally. It was suggested that this preference reflected the fact that ditches, and the weedy vegetation surrounding them, represented rich foraging sites, characterised by higher densities of nestling invertebrate prey (Mason and MacDonald 2000). Frequent use of ditches for foraging has been noted in other populations of Corn Bunting in the UK (Gillings and Watts 1997), and on the continent (Hustings 1997). Finally, other FaBI species that have shown to be positively associated with ditches include the Yellow Wagtail, Linnet, Goldfinch, and Kestrel (MacDonald and Johnson 1995; Parish *et al*. 1995; Bradbury and Bradter 2004).

Thus far, we have concentrated on whether ditches represent important habitat features for farmland birds, but it is also necessary to consider whether they benefit from the specific ditch management prescriptions instituted under ELS. To date, there have been no empirical studies of the possible benefits of ditch management for these species, but there are a number of reasons to expect such management to be beneficial. For example, the establishment of 2m buffer zones surrounding these water features should reduce contamination with agro-chemicals, thereby enhancing the abundance of aquatic prey for farmland birds (reviewed in Bradbury and Kirby 2006). The buffer strips themselves may also support relatively abundant terrestrial plant and invertebrate communities. Furthermore, these options also restrict the period during which bankside vegetation can be cut to between 15th Sept-28th Feb, which, because this is outside the peak breeding season of farmland birds, lessens the likelihood of active nests being destroyed by cutting operations.

It has been suggested that further benefits may be derived from agri-environment payments that encourage the creation and maintenance of ditches that remain damp all year round. (Peach *et al*. (2004). Currently, there are no such payments available under existing ELS prescriptions, but recent-Defra funded research is now examining the feasibility of creating such water features, and the potential benefits that farmland birds might accrue from the provision of these. The 'Wetting up Farmland for Wildlife' project has constructed bunded ditches, where ditches are dammed to allow more prolonged access to water for wildlife. Aquilina *et al*. (2007) contrasted the emergent insect biomass between experimentally bunded ditches and control ditches at regular intervals between April and August. These authors showed that the bunded ditches, which retained water longer, yielded significantly greater insect biomass than did control ditches, especially during the latter half of the study period (Aquilina *et al*. 2007). This finding implies that bunded ditches may offer rich foraging opportunities for farmland birds during the breeding season.

Winter season resources

The potential benefits of ditch management for farmland birds during the winter period are largely unknown, and additional research is required to investigate this issue. The provision of a 2m buffer zone surrounding ditches may afford similar winter foraging opportunities to those provided by conventional field margin buffer strips.

Conclusions and Recommendations

Sympathetic management of ditches in agricultural landscapes is liable to provide key nesting and foraging resources for a plethora of farmland birds, although further research is needed to identify the exact nature of these benefits. A recent review of agri-environment schemes in England argued that where current prescriptions were lacking was the provision of wetland features within arable systems (Vickery *et al*. 2004). Recent research into the creation of bunded ditches, and other small water features, shows that such management options could be valuable additions to the current suite of ELS prescriptions, maximising the benefits afforded by ditches for farmland birds (e.g. Aquilina *et al*. 2007). We have no recommendations to make for the improved delivery of these options.

Options for Trees and Woodlands

EC1 – Protection of in-field trees – arable
EC2 – Protection of in-field trees – grassland

Trees are of both historic and landscape significance in arable and pastoral agricultural areas of England (Anon 2005). These agri-environment prescriptions seeks to preserve the existence of in-field trees by placing restrictions on the levels of cultivation and agro-chemical input that can be applied within close proximity of them.

Breeding season resources

The primary benefit of protecting in-field trees for farmland birds is the provision of nesting opportunities. In particular, these options target the preservation of ancient trees, which are more likely than younger trees to comprise tree cavities suitable for hole-nesting species, such as the Kestrel, Barn Owl, Stock Dove, Jackdaw, Tree Sparrow and Starling. The availability of nest-sites is often cited as an important factor limiting the populations of such hole-nesting birds (reviewed in Newton 1998). In addition, some open-cup nesting species, including Goldfinch and Greenfinch, may construct nests within the canopy of in-field trees, although such nests might be especially susceptible to depredation.

In-field trees may also afford farmland birds with some foraging opportunities. Preservation of in-field trees effectively requires that the area beneath the tree canopy be taken out of agricultural production, which allows fragments of low-input arable/grassland to persist within the agricultural landscape. Although no studies have examined this issue explicitly, it is probable that these fragments, particularly those sited in arable fields, are characterised by a higher relative abundance of important dietary insects than the encompassing crop/pasture. Conceivably, the richness of a fragments' invertebrate community will depend on its degree of isolation from other source populations, especially for those species with a relatively poor dispersal capacity. Some farmland birds may also benefit from the provision of foliar insects in the canopy of in-field trees. Furthermore, seed-eating birds may profit from provision of uncultivated areas below in-field trees if arable weeds are permitted to develop and set seed. Buckingham (2007) suggested, however, that where such fragments are subject to excessive grazing pressure in pastoral regions, they are less likely to be of considerable benefit for seed-eating birds.

Winter season resources

It is unlikely that the protection of in-field trees will provide any FaBI species with key resources during the winter period.

Conclusions and Recommendation

Empirical evidence of the benefits afforded by this agri-environment option for farmland birds is lacking, but it is probable that it provides, at most, only modest resources for a handful of species. Clearly, its principle advantage is the provision of tree cavities for hole-nesting species, which are often scarce in the agricultural environment. We have no recommendations to improve the delivery of this option for farmland birds.

Options for Buffer Strips and Grass Field Margins

EE1-3 – 2/4/6m buffer strips on cultivated land
EE4-6 – 2/4/6m buffer strips on intensive grassland

In the modern agricultural landscape, field edges represent important remaining areas of uncultivated habitat, and as such, support significant biodiversity. The sympathetic management of these field edges could considerably enhance the resources available for a plethora of species in the farming environment. The field margin agri-environment options seek to encourage greater provision of uncultivated land at the edge of fields to increase the area available for wildlife. In addition, field margins have other beneficial roles. They function as a buffer zone between the crop and hedge, ensuring that agrochemicals do not despoil the majority of the margins' invertebrate and plant communities, and act as dispersal corridors facilitating movement across the agricultural environment.

Breeding season resources

Perhaps the most striking example of the potential benefits afforded by the provision of uncultivated grass margins derives from the recovering Cirl Bunting population in southwest England. Autecological studies demonstrated that this species forages in rough or semi-intensive grasslands during the breeding season for nestling invertebrate food, while largely avoiding intensively managed pasture (Evans 1997). Orthoptera (grasshoppers and crickets) appear to be particularly important to this species. This invertebrate group is severely adversely affected by intensive grassland management (van Wingerden *et al*. 1992). Consequently, the creation of extensive grass field margins was included as a management option in the Countryside Stewardship Scheme (CSS) designed to aid the recovery of this species. Peach *et al*. (2001) recently described how the application of the combined agri-environment options prompted an 83% increase in the population of the Cirl Bunting on CSS-managed land between 1992-1999, but specifically, the authors also stated that there is strong evidence for a positive influence of grass margins in the recovery. The provision of 6 m grass margins in CSS agreements had a significant influence on whether the populations supported under individual agreements gained additional Cirl Buntings (Peach *et al*. 2001).

Species included in the farmland bird index (FaBI) are also known to benefit from the provision of grass margins. For example, Bradbury *et al*. (2000) showed that the width of uncultivated grass field margins was strongly associated with the density of Yellowhammer territories in lowland farmland in southern England (see also Stoate and Szczur 2001; Stevens and Bradbury 2006). Yellowhammers will construct their nests in the herbaceous vegetation of grass margins, but the authors suggested that their principle benefit was as a rich foraging habitat (Bradbury *et al*. 2000). A subsequent study confirmed the speculations of Bradbury *et al*. (2000), demonstrating that foraging Yellowhammers utilised grass margins and other boundary habitats to a greater degree than cropped areas (Perkins *et al*. 2002). Another species known to benefit from the provision of grass margins at the boundaries of arable fields is the Whitethroat. Stoate and Szczur (2001) showed that territory occupancy in this species was also positively related with the width of grass margins. In this study, Whitethroats nested almost exclusively in the herbaceous vegetation of the margin, and consequently, this species probably benefited equally from the availability of suitable nesting habitat, and an abundance of invertebrate food (Stoate and Szczur 2001). Other species for which grass margins are also liable to provide suitable nesting and foraging resources include the Grey Partridge (Aebischer and Blake 1994), Corn Bunting (Wilson *et al*. 2007), Reed Bunting (Brickle and Peach 2004), and Chaffinch (Stevens and Bradbury 2006). Note, however, that not all studies have documented a positive effect of arable grass margins on farmland birds. Marshall *et al*. (2006) contrasted the abundance of seven bird species, including Yellowhammer and Whitethroat, on fields with and without sown margins, and was unable to determine a clear beneficial effect of the agri-environment option. However, it is unlikely that this study was conducted at a sufficiently large spatial scale to adequately detect changes in the distribution of bird territories attributable to the provision of field margins.

In addition to bird-habitat association studies, there is considerable evidence that grass field margins are a rich source of invertebrate prey for farmland birds. For example, Barker and Reynolds (1999) found that densities of sawfly larvae, a key constituent of the diet of many birds, were four-fold greater in grass margins than in conventional crops. The abundance of sawflies, and chick-food invertebrates more generally, was positively correlated with margin age (Barker and Reynolds 1999). In a study that examined the influence of 6 m grass margins on the prevalence of several invertebrate taxa, Marshall *et al*. (2006) demonstrated that bees and Orthoptera, but not spiders or Carabidae, were more abundant in the presence of grass field margins than in their absence. Furthermore, Pywell *et al*. (2007) showed that tussocky grass margins were characterised by an elevated abundances of bees, butterflies, spiders and bugs compared with conventional crop edges. Finally, as uncultivated grass is a habitat favoured by small mammals, it is also conceivable that raptorial birds, such as Barn Owl and Kestrel, may profit from access to grass field margins, particularly in arable agricultural landscapes. Shore *et al*. (2005) examined the abundance and biomass of small mammals on grass margins and conventional field edges, and showed that in autumn, but not spring, the densities of Bank Vole, and to a lesser extent Common Shrew, were higher in the former than the latter (see also Askew *et al*. (2007)).

Douglas *et al*. (in prep.) documented a seasonal shift in the relative use of uncultivated field margins by Yellowhammer during the course of the breeding season; margins were preferentially foraged on in early summer, but their use decreased in late summer, superseded in importance by cereal crops. This is despite the fact that important chick-food invertebrates in this study declined in cereal crops in late summer, but densities remained consistently high in the arable field margins. Rather than reflecting dissimilarities in food abundance, Douglas *et al*. (in prep.) suggested that this habitat shift was related to habitat-specific changes in food accessibility. During the study, the vegetation height increased in all agricultural habitat types, but the growth observed in field margins was especially pronounced. Consequently, it was suggested that the late-season vegetation architecture of field margins precluded access to invertebrate prey by farmland birds, thus rendering it a relatively unattractive foraging habitat (Douglas *et al*. in prep.). In a follow-up study, Douglas *et al*. (in prep.) experimentally altered the vegetation height of field margins (mowing out small patches of short vegetation) to test whether the utility of field margins late in the breeding season could be improved for foraging birds by the application of management. The authors showed that the use of mown field margins increased in late summer, particularly where margin vegetation exceeded 60 cm (Douglas *et al*. in prep). It was suggested that such active management of grass margins would increase their value for birds by extending their useful lifetime into late summer, and may reduce the reliance on cropped areas by some species (Douglas *et al*. in prep.).

Whether the value of grass field margins can be improved for foraging birds has been the focus of another, larger-scale study. Within the context of the SAFFIE study (Morris 2007; www.saffie.info), field margins were sown with different seed mixtures (Countryside Stewardship mix, tussock grass mix, and fine grass and forbs mix) and subject to three different forms of management (cutting, scarification, and selective graminicides) [1]. The type of management to which a field margin was subject significantly influenced its usage by farmland birds, with greater densities associated with scarified and graminicide-treated plots than cut margins (Henderson *et al*. 2007). This pattern of habitat selection was attributed to the preference of many farmland birds to forage in open, sparse vegetation structures, which affords easy access to prey items (Henderson *et al*. 2007). Moreover, foraging habitat selection of farmland birds was also affected by prey densities, with more present where the abundance of carabid beetles was high (Henderson *et al*. 2007). Numerical responses to spatial aggregations of prey are a well-documented phenomenon in farmland birds. Finally, in contrast to the effects of the various management regimes, type of seed mix exerted only a very weak influence on the foraging distribution of farmland birds (Henderson *et al*. 2007).

Grass field margins have been widely applied within arable farmland to counter the loss of biodiversity, but it is only recently that researchers have begun to consider the potential benefits they may afford in grassland-dominated regions. Defra (2007) manipulated field margins in improved grassland by applying one of seven management regimes, which ranged in their intensity from conventional silage management to no summer disturbance. The use of margins by both small insectivores and finches and buntings during the breeding season increased along the gradient of extensification, with an approximate twofold difference in density between the most and least intensive experimental treatments (Defra 2007). These patterns of habitat selection were interpreted as reflecting dissimilarities in food availability across the management regimes; in particular, most insect taxa (e.g. beetles, butterflies, true bugs, planthoppers and spiders) responded positively to the greater structural complexity of grass sward afforded by the extensive management regimes, increasing in both abundance and species richness (Defra 2007). In contrast, there were no discernible treatment effects demonstrated by large insectivores, which rarely foraged on grassland margins during the breeding season (Defra 2007). Defra (2007) suggested, as has recently been trialled for arable field margins (see above), that the value of these habitat features may be enhanced via the application of management techniques, including scarification or the use of graminicides, which function to ‘open up’ the grass sward, thus facilitating greater access to prey items by foraging birds.

Finally, it should be noted that in spite of the evident nesting and foraging opportunities provided by field margins, certain studies have highlighted drawbacks associated with their provision. For example, Cook *et al*. (2007) examined the provision of both undrilled plots and grass margins on the breeding productivity of Skylarks, and demonstrated that the success rate of nests in fields with grass margins was significantly lower than those nests without proximate margins. These authors suggested that grass margins were acting as linear corridors for terrestrial predators, thus facilitating greater to breeding attempts conducted in the crop (Cook *et al*. 2007). An alternative interpretation is that predators were attracted to the greater availability of food associated with margins, and inadvertently stumbled upon adjacent Skylark nesting attempts (Cook *et al*. 2007).

Winter season resources

In contrast to summer use of uncultivated field margins, relatively little is known about the use of these habitat features during the winter season (Vickery *et al*. 2002). This dearth of research is liable to be attributable in part to the prominence of overwintered stubbles as an important winter foraging habitat of farmland birds, but extensively managed grassland is also likely to provide important feeding opportunities for certain species, both in the form of seeds and overwintering invertebrates. Henderson *et al*. (2007) contrasted the densities of farmland birds during winter across field margins

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[1] The three experimental treatments applied in the SAFFIE study were intended to reduce the density of the margin sward, thus allowing greater access to the soil for foraging birds. The mowing management option is self-explanatory. Scarification involved the use of a power harrow to cultivate the top 2.5 cm of soil, aiming for 60% soil disturbance (i.e. 60% bare ground in early spring). Selective graminicides were used to kill off certain susceptible grass species within the sward, thus creating bare patches.

characterised by different seed mixtures and different management regimes. Seed mixture did not significantly influence patterns of winter habitat selection, but the type of management did. Specifically, statistical analyses modelling all species and granivorous species only indicated that densities of birds were more pronounced on field margins that received a cut in autumn than those remaining uncut. This finding was contrary to the initial predictions of Henderson *et al*. (2007), who anticipated that not cutting in autumn would leave more seed available for foraging birds, but the authors surmised that for birds that glean food from low vegetation or probe the soil, low cut swards may afford greater accessibility. In this study, the abundance of birds utilising field margins also declined temporally, implying that depletion of food resources occurs during the winter period (Henderson *et al*. 2007). In a study of winter field margin use in improved grassland, Defra (2007) demonstrated that large insectivores made proportionately greater use of intensively managed margins received frequent cuts. Echoing the conclusions of Henderson *et al*. (2007), this study also suggested that this finding was a reflection of the greater access to food resources provided by short swards (Defra 2007). Furthermore, management regime did not appear to considerable modify the habitat selection patterns of small insectivores, while finches and buntings rarely utilised the grass margins during the winter period. Finally, Hancock and Wilson (2002) evaluated patterns of winter habitat use of the Grey Partridge in Scotland. This species demonstrated strong positive associations with field boundary grass both at the 1 km square scale, and at the field scale.

Conclusions and Recommendations

This review provides convincing evidence that field margins provide essential resources for farmland birds, especially during the breeding season. However, there are a number of recommendations that may be advanced to increase the value of margins to these species. Firstly, the ELS handbook gives no guidance on the placement of field margins within the wider landscape, but where they are located can have important repercussions for the suite of farmland birds that exploit these margins. For example, Skylarks will not utilise margins that are bordered by tall boundary features such as hedges, but these will be used by Yellowhammers (T. Morris *pers. comm.*). Depending on the species present on individual farms, perhaps targeted deployment of field margins within the agricultural landscape would allow for optimal conservation of farmland birds (T. Morris *pers. comm.*.). There is a counter-argument, however, which suggests that the presence of suitable margin habitat on farms may facilitate the colonisation of these sites from source populations. Secondly, a recurring theme in this section on field margins is that the growth of field margin vegetation may obstruct access to the abundant food resources that they harbour, rendering it a relatively unattractive foraging site. We described several studies that endeavoured to improve the value of field margins to foraging birds by creating a more heterogeneous vegetation structure, characterised by tussocks of dense grass interspersed by open, sparse areas of sward. In particular, scarification and the use of selective graminicides appear to be especially valuable in this respect, and consequently, these may be management options that is would be beneficial to implement more widely. Thirdly, there is a supplement to option EE3 that permits the sowing of part or all of the field margin with a seed mixture of fine-leaved grasses and forbs (Anon 2005). This supplement is liable to provide farmland birds with key nesting and foraging resources. However, because the establishment of such seed mixtures is expensive, that the supplement is not associated with an additional point allocation is liable to be a disincentive (T Morris. *pers. comm.*). The points allocation for this supplement should acknowledge the extra expense associated with the establishment of this seed mixture (T. Morris *pers. comm.*.). Finally, a stipulation of grass field margin prescriptions is that they should be placed next to grass fields receiving an input of 100 kg/ha or more of fertiliser. The biodiversity benefits of creating field margins next to fields with lesser fertiliser inputs would seemingly be as great or greater than margins located next to more intensively managed fields, and therefore, it is not clear why such should be excluded from this option (R. Winspear *pers. comm.*.).

EE7 – Buffering in-field ponds in improved grassland
EE8 – Buffering in-field ponds in arable land

These agri-environment prescriptions seek to establish 10 m buffer strips around in-field ponds, with the aim to prevent nutrient leaching or run-off from the surrounding farmland. Maintaining the water quality of these ponds will therefore permit the establishment of rich aquatic flora and fauna, which in turn will provide valuable nesting and foraging resources for a suite of farmland birds.

Breeding season resources

No studies have explicitly evaluated the use of 10 m buffer strips around in-field ponds by farmland birds, but its is probable that they will provide comparable resources to those afforded by traditional field edge grass margins (see above). The only conceivable difference may be that, if the ponds are not proximate to adjacent vegetation, birds will be reluctant to utilise these habitat features because the perceived predation risk is too great. Furthermore, another by-product of buffering in-field ponds is that a healthy aquatic biotope is retained, affording suitable conditions for associated plants and invertebrates. Bradbury and Kirby (2006) recently reviewed the ways in which farmland birds profit from the provision of small-scale water features within the agricultural landscape, outlining four principle benefits. Firstly, certain invertebrate taxa have an obligate aquatic life-history stage, such as the Odonata and Chironomid midges, and these water-dependent invertebrates are a favoured prey item of several farmland birds, including Yellow Wagtail (Davies 1977; Nelson 2003), and Tree Sparrow (Anderson *et al*. 2002). Secondly, the provision of water features affords the opportunity for rank wetland vegetation to become established, which provides vegetative cover for nest sites, and a suitable habitat for invertebrates (Bradbury and Kirby 2006). In particular, Reed Buntings are known to exhibit a strong preference for both nesting and foraging in rank vegetation associated with ponds and other water features (Brickle and Peach 2004). Thirdly, vegetative growth is often restricted on ground that is subject to periodic flooding, and this provides at the edge of wetlands a sparse sward cover that enables ground-foraging birds greater accessibility to prey items (Bradbury and Kirby 2006). Species liable to benefit in this respect include the Lapwing, Yellow Wagtail, Corn Bunting and Tree Sparrow (Bradbury and Kirby 2006). Lastly, damp soil associated with water features often harbours a rich soil macro-invertebrate community (e.g. earthworms), which is easily accessible to foraging farmland birds, such as Song Thrush, because of its greater relative penetrability (Bradbury and Kirby 2006).

Winter season resources

Similar to breeding ground resources, 10 m buffer strips around in-field ponds are liable to provide analogous winter resources to conventional field boundary grass margins, including weed seeds and overwintering invertebrates. Bradbury and Kirby (2006) suggested that Reed Bunting, Tree Sparrow, and Yellowhammer may also benefit from the provision of sparse vegetation at the margins of water features, because they afford greater access to seeds and insects.

Conclusions and Recommendations

Providing grass buffer strips around in-field ponds is liable to be doubly beneficial for farmland birds. Not only do the margins themselves offer rich nesting and foraging conditions for many species, but they also preserve the integrity of the pond biotope, which itself offers a disparate suite of nesting and foraging opportunities. Furthermore, at a landscape scale, the provision of buffer strips and pond significantly augments the habitat heterogeneity present in the agricultural environment. Buckingham (2007) suggested that for ponds sited in improved grassland, permitting livestock to graze the shoreline would provide a valuable drinking place for birds and may provide suitable habitat for rare draw-down zone plants and insects. We have no recommendations to improve the delivery of this option for farmland birds.

Options for Arable Land

EF1 – Field corner management
EK1 – Take field corners out of management
EL1 – Field corner management (LFA land)

These ELS prescriptions encourage farmers to remove field corners, or other areas of unproductive land, from management as a general means by which to improve the agricultural environment for biodiversity. The arable option (EF1) permits a maximum unmanaged patch size of one ha per 20 ha of arable land, while the grassland options (EK1, EL1) allow up to three 0.5 ha plot in 10 ha of grassland. Implementation of these prescriptions should increase the habitat heterogeneity within the wider countryside, providing grassland patches in predominantly arable farming regions, while also promoting areas of extensive pasture in intensively-managed pastoral landscapes.

Breeding season resources

The provision of unmanaged field corners is a targeted management prescription in the conservation of the Corncrake. ‘Corncrake corners’, as they have been coined, aim to provide crucial early and late season vegetative cover, which is often lacking prior to the growth of, and subsequent to the harvest of, suitable hay and silage meadows (O’Brien *et al*. 2006). Increased availability of such tall vegetation is thought to afford greater concealment for both adults and juveniles from predation (O’Brien *et al*. 2006). In contrast to the Corncrake, the potential benefits of removing field corners from agricultural production have rarely been considered for FaBI species. Given that these plots quickly revert to rank grass and scrub, it is conceivable that species such as Yellowhammer, Grey Partridge, and Corncrake may seek nesting sites within them (Buckingham 2007; Wilson *et al*. 2007). Furthermore, the tall vegetation is also liable to harbour a diverse and abundant assemblage of invertebrates, which may represent profitable foraging sites for some farmland birds(e.g. Corn Bunting, Wilson *et al*. 2007); however, it should be noted that reduced accessibility to potential prey may render these sites relatively unattractive to certain species. Finally, small mammals thrive in areas where rank grass is permitted to develop, and these areas are liable to prove fruitful foraging grounds for raptorial birds, including Barn Owl and Kestrels (Askew *et al*. 2007).

Winter season resources

Similar to breeding ground resources, whether farmland birds benefit from the provision of unmanaged field corners during winter has received little explicit attention. Presumably, potential beneficiaries of these habitat features include Grey Partridges, which are liable to seek refuge from predators in the thick vegetation, and Barn Owls and Kestrels, which will probably utilise these corners as foraging habitats.

Conclusions and Recommendations

The extent to which field corner management will benefit farmland birds is not clear from existing research but benefits for many species are likely given that these will increase heterogeneity and the extent of uncropped or low intensity farmland. In the absence of direct research, several general recommendations can be made to try and increase the benefits of these agri-environment options for FaBI species. Currently, all of the prescriptions stipulate that following establishment, the field corner should not be cut more regularly than once every five years to facilitate the development of tussocky grass and low scrub. However, there are no specified dates during which mowing should occur, which means this management could be implemented during the breeding season, resulting in the destruction in nests. Therefore, a stipulation precluding the occurrence of mowing between 1st March and 31st August could be added to the option (T. Morris *pers. comm.*). Furthermore, there is a supplement to the arable option (EF1) that permits the sowing of a mix of fine-leaved grasses and forbs within field corners, which would provide abundant foraging resources for seed-eating and insectivorous farmland birds. However, this supplement is not associated with an additional point allocation, and because the sowing of such seed mixes can be prohibitively expensive, the uptake of this option is liable to be negligible without the appropriate motivation through the allotment of extra points (T Morris *pers. comm.*). Finally, Buckingham (2007) suggested that unmanaged field corners in grassland-dominated landscapes may deliver more suitable foraging resources for some farmland birds if a low aftermath grazing regime is applied.

EF2 – Wild bird seed mixture
EF3 – Wild bird seed mixture on set-aside land
EG2 – Wild bird seed mixture in grassland areas

A dearth of winter food resources, particularly seeds, is thought to be an important driver in the declines of several farmland birds in Britain. Recognising the role of winter food limitation, the above options encourage the cultivation of seed-bearing crops, such as Kale *Brassica oleracae viridus*, Quinoa *Chenopodium quinoa* and Millet *Sorgum halepense*, to provide an alternative supply of winter food. Planting of game crops has been permissible on set-aside under the Wild Bird Cover option since 1993, but payments for their cultivation on arable and grassland have only been available since 2002. Evidence from several studies demonstrates that wild bird seed crops are an invaluable source of food for farmland bird species, especially during the winter period when natural food stocks are at their most depleted, but also in summer.

Breeding Season Resources

No studies have explicitly examined whether wild bird crops offer suitable nesting opportunities for farmland birds. Given our current understanding of the nesting habits of FaBI species, three that may benefit from the provision of these crops are the Grey Partridge (Potts 1986), Reed Bunting (Brickle and Peach 2004), and Corn Bunting (Clare Mucklow *pers comm.*.), but, obviously, the main aim of this option is to provide key food resources.

As regards foraging opportunities, Parish and Sotherton (2004) demonstrated in an arable region of eastern Scotland that the density of songbirds in wild bird crops during summer was 80 times greater than that of conventional crop types. Similar patterns were evident in subsets of the data comprising finch (Chaffinch, Greenfinch, Goldfinch, Linnet, Bullfinch) and thrush (Blackbird, Song Thrush and Mistle Thrush) observations only (Parish and Sotherton 2004). Furthermore, Murray *et al.* (2002) showed that Skylarks provisioning young preferentially foraged in kale- and cereal-based wild bird crops, whilst cereals and broad-leaved crops were exploited less than expected. These non-random patterns of habitat use appear to be a reflection of underlying differences in food availability. For example, in a study contrasting the abundance of invertebrates in cropped and non-cropped agricultural habitats in Leicestershire, Moreby and Southway (2002) discovered that wild bird crops harboured the highest densities of important bird food taxa, including Araneae, Homoptera, Heteroptera and Carabidae. Similarly, Pywell *et al.* (2007) demonstrated that insect abundance and arable weed species richness was more pronounced in wild bird crops than in the surrounding conventionally managed fields. Note that this increased insect and arable weed abundance in wild bird crops is in addition to the rich seed resources provisioned by the crop plants themselves.

Few studies have assessed the effects of wild bird crops on patterns of reproductive success in farmland birds, but recently, this was done for a population of Grey Partridge in France (Bro *et al.* 2004). This study showed that, in spite of provisioning two types of wild bird crop, one cereal-based and one kale-based, which were developed to provide refuge from predators and chick invertebrate food respectively, there were no apparent effects of wild bird crops on the productivity of this species (Bro *et al.* 2004). Although this study has been subsequently criticised it highlights the problems in scaling up plot-size studies to the landscape level.

Winter Season Resources

Empirical studies have shown that wild bird crops can constitute an important resource for foraging farmland birds during the winter period. For example, Henderson *et al.* (2004) showed that on certain preferred types of wild bird crop, bird densities were 50 times greater than observed on conventional crops. Furthermore, of 18 species documented by this study, 15 exhibited significantly higher abundances on wild bird crops than conventional crops, including several species that have declined precipitously in the British agricultural landscape in recent decades (e.g. Tree Sparrow, Linnet, Reed Bunting and Yellowhammer; Henderson *et al.* 2004). Exceptions to this general pattern were the Skylark, Grey Partridge and Corn Bunting, all of which demonstrated equivalent or greater usage of cereal stubbles than wild bird crops (Henderson *et al.* 2004). In another study, Stoate *et al* (2003) showed that the overall bird density at a study site in northern England was 420 individuals/km^2 following the establishment of wild bird seed crops, which is in stark contrast to the average winter density of 30-40 individuals/km^2 noted on standard crops across a large sample of English farms during the same period. Moreover, in this study, farmland birds did not exploit wild bird crops equally throughout the winter period, but usage increased during early winter (Oct-Nov), peaked in mid-winter (Dec-Jan), and declined in late winter (Feb-Mar). Finally, Pywell *et al.* (2007) showed that Wood Mouse activity was higher in wild bird seed mix than the adjacent crop during winter, which suggests that these strips might represent profitable foraging habitats for raptorial farmland birds, including Kestrel and Barn Owl.

Although initially developed as an arable agri-environment prescription, the use of wild bird crops is increasingly being advocated in grassland (Henderson *et al.* 2004; Stoate *et al.* 2004). Defra (2007) manipulated the structural and compositional complexity of field margins in improved grassland by applying various management options, one of which was the sowing of a wild bird seed mixture. As expected, wild bird crops were heavily utilised by granivorous passerines during the winter, which was attributed to greater food availability in wild bird crops than improved pasture. Furthermore, small and large insectivores also frequented the wild bird crop during the winter. Defra (2007) posited that the wild bird crop's heterogeneous sward structure probably afforded easy access to invertebrate prey. Furthermore, in another study, Henderson *et al.* (2004) demonstrated that the difference in densities between wild bird crops and the surrounding fields was significantly greater in grassland than arable areas for six bird species (3 FaBI species: Tree Sparrow, Linnet, Reed Bunting). One interpretation of this finding is that food resources are less abundant in pastoral regions for these species, necessitating greater concentration of birds at a small number of food rich sites. Stoate *et al.* (2004) speculated that wild bird crops could have a special role in grassland areas, effectively introducing arable pockets to grassland landscapes and increasing both the food resource and habitat heterogeneity.

An important aim in the study of wild bird crop use by farmland birds has been establishing the seed preferences of different species; this information has then been used to inform the seed composition of wild bird seed mixtures (Stoate *et al.* 2003; Henderson *et al.* 2004). For example, Henderson *et al.* (2004) suggested that a principal constituent of any seed mixture should be kale, which was present within the top three ranked crops for 14 of 18 species in their study. Although this crop encompassed only 0.8% of the study area, 11% of all Greenfinch and Linnet records, and 28% of Tree Sparrow observations were documented in kale (Henderson *et al.* 2004). In addition, quinoa was another seed heavily favoured by certain farmland birds (Henderson *et al.* 2004). Twenty-six per cent of all Tree Sparrows were observed in fields containing quinoa, while 10% of Greenfinch and Reed Bunting registrations were also noted from this crop (Henderson *et al.* 2004). Not all farmland birds, however, would be adequately provisioned for with a seed mixture comprising kale and quinoa only; in particular, Yellowhammer and Corn Bunting preferred to feed on cereal grains, such as barley and triticale, whereas Wood Pigeon and Goldfinch favoured maize and rape crops respectively (Henderson *et al.* 2004; Brickle and Harper 2000). Henderson *et al.* (2004) concluded that an optimal seed mixture that would fulfil the collective needs of a wide spectrum of farmland birds during the winter period would therefore consist of kale, quinoa and cereal grains, although the authors did stipulate that some flexibility should be permitted in the composition of wild bird seed crops to facilitate local targeting for specific declining birds.

Some evidence suggests that when deploying wild bird seed crops in the agricultural landscape, consideration needs to be given to its placement relative to other habitat features. For example, Henderson *et al*. (2004) showed that the densities of Greenfinch and Yellowhammer were highest in plots characterised by an abundance of hedgerow boundary, whereas Tree Sparrow, Greenfinch and Linnet were positively associated with taller hedgerows. In contrast, Corn Buntings were more prevalent in plots with open boundaries and lower hedge heights (Henderson *et al*. 2004). A good understanding of the influence of other habitat features is liable to be particularly necessary where wild bird seed crops are established with species-specific conservation in mind (Stoate *et al*. 2004).

Bro *et al*. (2004) assessed whether the provision of wild bird crops influenced the overwinter survival rate of Grey Partridges in France. The authors showed, contrary to their initial predictions, that overwinter survival was higher in control farmland plots that lacked wild bird strips than experimental plots with such strips (Bro *et al*. 2004). It was suggested that a predation trap scenario, whereby Grey Partridges are subject to high predation pressure in the wild bird crops, either because predators are attracted to aggregations of prey, or because they typically forage along linear habitat features, might elucidate these findings (Bro *et al*. 2004). Bro *et al*. (2004) also stressed that this result illustrates the importance of assessing population dynamics rather than patterns of density or habitat use when attempting to establish the precise repercussions of the provision of particular agri-environment prescriptions. This is certainly more biologically meaningful but it is also extremely difficult to correct. In considering the value of habitats under ELS options it is important to acknowledge that high density habitats may not necessarily enhance productivity and/or survival.

Conclusions and Recommendations

There is good evidence that wild bird crops can be an important source of food for farmland bird, particularly in winter, but also summer. Uptake at a considerable scale could play a key role in the reversal of declining farmland bird population trends. However, a number of changes may be suggested to the existing ELS prescriptions to improve even further its delivery for these species. Firstly, the provision of wild bird crops is likely to be most valuable for farmland birds when the availability of natural food is lowest (e.g. late winter, Feb.-Mar., Evans et al 2004); however, there are currently no stipulations regarding the cultivation and cutting dates of these crops, which means that they can be legitimately removed prior to this period of greatest need (Siriwardena *et al*. in press). Although most crops have lost their seeds by late season, several arable weeds within these crops will germinate and set seed replenishing this food resource. Thus the specification of a date before which wild bird crops cannot be destroyed may ensure their provision encompasses this critical period (Siriwardena *et al*. in press). In addition, it may be valuable to investigate the extent to which modifications of the species, establishment and/or management of different seed-bearing crops could provide this late season food . Secondly, the EF2 prescription (wild bird seed mixture) permits wild bird crops to be established either as a mixture, or in species-specific strips, but the EF3 prescription (wild bird seed on set-aside land) stipulates that it may only be sown as a mixture (Anon 2006). A potential problem associated with sowing mixtures is that different seeds vary in their optimal growing conditions (Henderson *et al*. 2004). For example, kale-quinoa seed mixtures are typically sown in late April, because quinoa is not frost-hardy, yet kale becomes better established when sown early (Henderson *et al* 2004). Thus, cultivating crops in parallel strips facilitates independent husbandry according to the particular requirements of individual species (Henderson *et al*. 2004). There is therefore a strong argument for relaxing the EF3 prescription, and allowing the cultivation of species-specific strips. Henderson *et al*. (2004) emphasised that crop flexibility is liable to be important for widespread, cost-effective uptake and environmental management based on local conditions. Thirdly, another stipulation of the EF2 prescription is that fertiliser should only be applied to crops if needed for establishment. However, it is known that some of the wild bird crops actually require fertilisers to successfully produce a seed crop (R. Winspear *pers comm*.). Relaxing this requirement may therefore be advisable in some cases. Fourthly, a restriction of the placement of wild bird seed mixture in grassland areas is that it should not be located in fields that have been in permanent grass for more than five years. It is conceivable, however, that, especially if these fields have been managed as improved pasture, natural levels of seed availability will be particularly impoverished, and hence, they may derive the greatest biodiversity benefits from the establishment of wild bird seed mixtures (R. Winspear *pers comm.*).

Common agricultural pests (e.g. flea beetles *Phyllotreta* spp. and pollen beetles *Meligethes* spp.) can be damaging to constituents of the wild bird seed mixtures, which may result in poor establishment and seed yield for farmland birds during the winter. Consequently, a recent Defra-funded study attempted to devise a effective, environmentally sustainable pest control regime for wild bird crops managed under environmental stewardship (BD1623, CEH 2007). This study derived the following recommendations for the management of these crops. Firstly, vary the composition of seed mixtures between patches and always include a range of pest resistant insurance species. For example, this study demonstrated that quinoa and millet were relatively insensitive to the effects of invertebrate pests. Secondly, avoid sowing too early (April – May recommended) into cold, dry or otherwise poor quality seed beds, because this is liable to reduce the probability of successful establishment. Thirdly, avoid establishment adjacent to oilseed rape, which is liable to be a reservoir and colonisation point of agricultural pests. Fourthly, rotate the location of the patch every 1-2 years to avoid a build up of pests. Fifthly, dress the seeds of susceptible species (fodder radish, kale, and linseed) with a combined insecticide and fungicide to reduce flea beetle damage in spring. Lastly, avoid summer pesticide application if possible to reduce the risk of significant damage to non-target invertebrate populations (Pywell *et al*. 2007).

EE3 supplement – Wildflower and grass mixture on 6 m margins
EF4 – Pollen and nectar flower mixture
EF5 – Pollen and nectar flower mixture on set-aside land
EG3 – Pollen and nectar flower mixture in grassland areas

The development of the above agri-environment prescriptions have been motivated by the desire to provide suitable foraging habitats for key insect pollinators, such as bumblebees and butterflies, many of which have declined steeply in the British agricultural environment. Although the first option is categorised under buffer strip prescriptions, it was decided to incorporate it in with the pollen and nectar flower mixture options to differentiate those field margin prescriptions that explicitly cater for the needs of pollinators and those that do not. The primary difference between the wildflower and pollen and nectar mixtures is in their species composition, with the former characterised by a greater proportion and species richness of perennial dicots and fine-leaved grasses, while the latter comprises more annual dicots (Pywell *et al*. 2006).

Breeding Season Resources

With the exception of wildflower margins in arable landscapes, the potential benefits afforded by the above ELS prescriptions for farmland birds have yet to be examined fully. However, it is likely that at least some findings from the research of wildflower margins are generally applicable across the other options. Weibel (1999) investigated the influence of wildflower strips on patterns of nest-site selection, breeding productivity and foraging behaviour in a population of Skylark in Switzerland. Relative to their availability in the landscape, Skylarks demonstrated a preference for both nesting and foraging in wildflower margins (Weibel 1998; Weibel 1999). Wildflower strips are often characterised by tall, dense sward architecture, but previous habitat association studies have suggested that Skylarks avoid such vegetation structures (refs). Weibel (1998; 1999) attempted to reconcile this finding by suggesting that wildflower strips are characterised by pronounced structural heterogeneity, such that pockets of tall herbaceous vegetation are interspersed by areas of sparse, short swards, which may be attractive to nesting and foraging Skylarks. Furthermore, although it is not apparent from the either of these studies, presumably wildflower margins were not sited in close proximity to tall boundary features, which would otherwise dissuade Skylarks from exploiting these habitat features as nest or foraging sites.

Weibel (1998) suggested that the preferential use of wildflower margins by foraging Skylarks reflected the greater densities of invertebrate prey in this habitat type compared to other agricultural habitats. Support for this assertion comes from the study of Pywell *et al.* (2007), who contrasted the abundance and species diversity of invertebrates in different types of fields margin, including wildflower strips. The authors showed that wildflower margins were characterised by a greater abundance of Araneae, Hemiptera and Lepidoptera than conventionally managed crop (Pywell *et al.* 2007). Furthermore, this study also found that the invertebrate assemblages of pollen and nectar flower strips were comparable to those of wildflower margins, which implies that the former habitat may provide farmland birds with equally as rich foraging pickings as the latter. However, it should be noted that the value of potential foraging habitat for birds is a function of both food abundance and accessibility, and as discussed above, the tall, dense sward structure of wildflower and pollen and nectar flower margins may render these relatively unattractive foraging prospects for many farmland birds.

Weibel (1999) also showed that the provision of wildflower margins affected the reproductive success and fledgling growth rates of Skylarks, although in a rather complex and inconsistent manner. Clutch sizes were larger in breeding territories that encompassed wildflower strips than those that did not (Weibel 1999). However, elevated clutch sizes did not then translate to enhanced reproductive success in wildflower strips; instead, these margins were actually characterised by one of the lowest breeding productivities (18%, Weibel 1999). Predation was the foremost cause of reproductive failure in this population of Skylark, accounting for 71% of all nest losses. Weibel (1999) suggested that wildflower margins operated as a predation trap for breeding Skylark, because by aggregating high densities of nests within linear habitat features, they were relatively easily detected by foraging mammalian predators (as also suggested by Donald *et al.* (2002) for Skylarks in set-aside). The highest reproductive success observed in this study was found in winter-sown cereals, which is consistent with the findings of other detailed studies of reproduction in this species (e.g. Donald 1999). Furthermore, the feather growth rate of fledglings was significantly greater where parental territories incorporated wildflower margins compared to those that did not (Weibel 1999). This difference was especially pronounced during periods of inclement weather.

Finally, in a study of a reintroduced Grey Partridge population in Switzerland, Buner *et al.* (2005) found that the distribution of ecologically enhanced areas (e.g. wildflower strips and hedges) dictated the territory locations of this species in the wider landscape. Using data from radiotracked individuals, these authors showed that, depending on the season, 9-23% of all tracking locations were recorded within wildflower strips or hedges, in spite of the fact that these habitat features only constituted 2.6% of the total study area (Buner *et al.* 2005). Furthermore, 65% of all tracking locations were within less than 100m from the nearest ecologically enhanced area (Buner *et al.* 2005). Relative to their availability in the agricultural environment, wildflower field margins were a strongly preferred habitat type for the Grey Partridge during the breeding season, especially in summer (Buner *et al.* 2005). This pattern of habitat use was interpreted as being related to predator avoidance (Buner *et al.* 2005).

Winter Season Resources

Whether wildflower and pollen and nectar flower margins provide resources for farmland birds during the winter period has rarely been investigated. In the only study of which we are aware, Buner *et al.* (2005) demonstrated that Grey Partridge were heavily associated with wildflower strips during both autumn and winter.

Conclusions and Recommendations

There are some indications that wildflower field margins can provide key resources for certain farmland birds, particularly during the breeding season, but additional research is required to investigate the use of pollen and nectar strips. Recent research to improve pollen and nectar strips for invertebrates has focussed on prolonging the longevity of these resources during the summer by devising seed mixtures and cutting regimes that encourage the provision of late-season forage (BD1623, CEH 2007). This research demonstrated that cutting the pollen and nectar margins in early June (but no later) significantly enhanced and extended the provision of pollen and nectar resources available for invertebrates (Pywell *et al*. 2007). However, it should be noted that cutting operations are liable to destroy the breeding attempts of ground-nesting birds that choose to locate their nests in the pollen and nectar margins. Furthermore, after a few years of establishment, the grass component of the pollen and nectar mixtures often out competes the legumes, resulting in the creation of a simple grass margin. Although a more expensive option, the use of grass-free seed mixtures should be encouraged, because wildflower persist in these margins for a longer duration, thus providing an extended period of benefit (R. Winspear *pers. comm.*).

EF6 – Over-wintered stubbles

The decline of granivorous passerines in British farmland has been attributed to reduction in the availability of winter food, precipitated primarily by the loss of over-wintered stubbles (Wilson *et al*. 1996). Over-wintered stubbles can be a rich source of seeds, both in form of spilt grain and from arable weeds, but stubbles have become less abundant in the agricultural environment due to the widespread substitution of spring-sown crop varieties with winter-sown alternatives (Wilson *et al*. 1996). Those stubbles that remain are also less food rich for birds as a result of better harvesting techniques (less grain) and improved weed control (less weed seed). This agri-environment option seeks to encourage the retention of over-wintered stubbles to provide suitable seed-rich foraging habitats for granivorous farmland birds during the winter period (Anon 2005). There is convincing evidence that the provision of such habitats has positive effects on these target species, even to the extent of enhancing local population levels (see below).

Breeding Season Resources

The development of the over-wintered stubbles prescription was motivated by the desire to provide winter food to farmland birds, not breeding season resources. However, a by-product of the retention of stubbles is the subsequent presence of a spring crop. Spring-sown crops are known to benefit several species of farmland birds, providing both key nesting and foraging opportunities. A good example of a species strongly associated with spring tillage during the breeding season is the Lapwing (Wilson *et al*. 2001). This species favours nest-sites in areas of sparse or no vegetation (Berg *et al*. 1992; Sheldon 2002), a preference that appears to be related to its specific predator defence strategies. Because spring-sown crops are sown much later than their winter-sown counterparts, their sward height is correspondingly lower at the beginning of the breeding season, and they are therefore a more attractive prospect to settling Lapwing (Sheldon 2002). However, it should be noted that there is some evidence to suggest that spring cereals are an ecological trap for Lapwing. Sheldon (2002) showed that the daily survival rates of nests in spring cereals were only one half those of nests in winter-sown crops and other spring-sown crops, and only one third that of Option 1B fields (Arable Stewardship Pilot Scheme option – overwintered cereal or linseed stubbles, followed by spring/summer fallow). Poor survival rates of nests in spring-sown cereals was attributed to nest destruction during agricultural operations (Sheldon 2002).

Another species that appears to benefit from the provision of spring-sown crops is the Corn Bunting (see also relevant literature for Skylark). For example, Brickle and Harper (2000) examined the habitat composition within 150m of this species nests relative to that in the entire study area, and demonstrated that, next to grass field margins, spring-sown barley was the most favoured crop type. Similarly, Brickle *et al*. (2000) observed the foraging locations of breeding adult Corn Buntings, and showed that grass margins and spring-sown barley were also preferred relative to their availability in the wider countryside. The authors attributed these preference to greater associated food availability, because, sampling the density of four important chick-food invertebrate taxa in different agricultural habitats, they demonstrated that abundances were most pronounced in unintensified grassland and field margins, but were also relatively high in spring-sown barley (In contrast, intensively managed grassland and winter-sown wheat were characterised by the most impoverished invertebrate abundances (Brickle *et al*. 2000). Greater food abundances in spring-sown cereals relative to other crop types may be due to the fact that, in general, these crops are subject to fewer pesticide applications (Brickle *et al*. 2000).

Winter Season Resources

The preference of seed-eating farmland birds for stubbles during the winter period is well established. For example, Wilson *et al*. (1996) documented patterns of winter habitat association in 26 species, demonstrating that ten of these, including Greenfinch, Reed Bunting, Linnet, Yellowhammer, Goldfinch, Skylark, and Grey Partridge, used over-wintered stubbles more regularly than expected from their availability in the landscape. These findings have been replicated consistently in a plethora of other single- and multi-species studies (Donald and Evans 1994; Evans and Smith 1994; Wakeham-Dawson and Aebischer 1998; Buckingham *et al*. 1999; Bradbury and Stoate 2000; Moorcroft *et al*. 2002; Butler *et al*. 2005).

Moorcroft *et al*. (2002) examined the association between granivorous farmland birds and over-wintered stubbles more closely by examining between- and within-field patterns of foraging habitat use, and found that these were largely dictated by the distribution of seed food resources. This study showed that stubble field occupancy of five species, namely Woodpigeon, Skylark, Linnet, Reed Bunting and Corn Bunting, was significantly influenced by preceding crop type, with all species except Woodpigeon favouring barley stubbles over other stubble types (Moorcroft *et al*. 2002). Barley stubbles are characterised by a short, less dense straw, which facilitates the establishment of arable weeds, permitting greater weed seed production, while also maintaining areas of bare earth, which affords enhanced accessibility to seed resources by foraging birds (Moorcroft *et al*. 2002). Interestingly, this study also showed that Linnets and Reed Buntings were rarely found feeding in fields where densities of important dietary weed seeds fell below 250 seeds m^{-2} (Moorcroft *et al*. 2002). Similarly, Yellowhammers and Grey Partridges generally avoided foraging in stubble fields where cereal grain density was less than 50 seeds m^{-2} (Moorcroft *et al*. 2002).

The influence of seed density in stubble in the subsequent use of that stubble by birds has been demonstrated in a large number of studies (Robinson & Sutherland 1991; Wilson *et al.* 1996; Moorcroft *et al.* 2002; Robinson 2004; Vickery *et al.* 2005;). In fact, the majority of stubble fields currently support very few birds in winter (Vickery et al 2005). Gillings and Fuller (2001) suggested that only 50% of stubble fields support skylarks in winter. Robinson (2004) and Vickery et al (2005) demonstrated a clear link between pesticide management of the preceding crop and the level of foods resources for birds the following winter. These studies emphasise two key management issues. First, that stubbles designed to provide food for birds in winter must be actively managed with this aim in mind, namely by reducing inputs to the preceding crop. Second, that if such management is implemented, the area of stubble required to effect population recovery could be greatly reduced, perhaps by as much as 50%. It is encouraging that prescriptions exist under ELS for stubble preceded by low input crops .

To maximise the benefits of over-wintered stubbles for farmland birds, ELS stipulations have concentrated on management options that seek to enhance food abundance, but recent studies indicate that the value of stubbles may also be improved, at least for some species, by exploiting aspects of foraging behaviour. Butler *et al*. (2005) contrasted the use by farmland birds of two types of wheat stubble fields, one conventional, and the other in which the straw had been cut to create a lower vegetation structure. These authors demonstrated that granivorous passerines were significantly more prevalent in short- than long-stubble fields, whereas, conversely, Skylarks and Grey Partridges favoured long- to short-stubble fields (Butler *et al*. 2005). As seed densities were equivalent within the separate treatments, these disparate patterns of field use are unrelated to food abundance; instead, the authors invoked dissimilar predator avoidance strategies to explain their differential use (Butler *et al*. 2005). Specifically, while granivorous passerines tend to rely on early detection of predators to then allow them to flee to protective cover, Skylarks and Grey Partridges prefer to conceal themselves in the vegetation to evade detection (Butler *et al*. 2005). Therefore, the different species groups appear to be opting for stubble fields that best suit their respective predator escape strategies (Butler *et al*. 2005). Butler *et al*. (2005) concluded that the value of wheat stubble fields may be increased for granivorous passerines by simply lowering the vegetation height. However, they conceded that wholesale reductions may be deleterious for certain species (e.g. Skylark and Grey Partridge), and instead, advocated an increase in the structural heterogeneity of stubble fields, with some being cut and some not (Butler *et al*. 2005). Further investigating this issue, Whittingham *et al*. (2006) considered whether a combination of both topping (see above) and scarification (light cultivation technique that results in the disturbance of topsoil) was an effective technique with which to improve the value of stubbles for foraging birds. However, at least in this study (which was carried out on heavy soils only), scarification appeared to effect few additional benefits over and above those mediated by cutting.

A recent study has demonstrated that the availability of over-wintered stubbles can play an important role in dictating both the local winter distribution and population trends of declining farmland bird species (Gillings *et al*. 2005). Firstly, Gillings *et al* (2005) showed that Breeding Bird Survey (BBS) squares comprising a significant area of stubbles were characterised by more wintering birds than those with relatively little stubble. The implication was that squares encompassing more stubbles attracted birds in from the wider countryside (Gillings *et al*. 2005). Species responding positively to the availability of stubbles included Grey Partridge, Skylark, Tree Sparrow, Greenfinch, Goldfinch, Linnet, Yellowhammer and Reed Bunting (Gillings *et al*. 2005). Secondly, the authors also found that, for eight species (6 FaBI species; Skylark, Yellowhammer, Lapwing, Stock Dove, Starling and Goldfinch), the proximate availability of over-wintered stubble had a positive impact on its subsequent local population trend (Gillings *et al*. 2005). For Skylark, populations in BBS squares with less than 10 ha of stubbles declined by 20%, whereas those with greater than 10 ha only fell by 4% (Gillings *et al*. 2005). Importantly, the threshold stubble area at which Skylark populations appeared to reach approximate stability was 20 ha per square (Gillings *et al*. 2005). However, as indicated above, this area could be greatly reduced if these stubble followed low input crops. This study is exceptional in farmland bird research in providing an informed answer to the question of how much managed habitat is required within the agricultural landscape to engender a reversal of species population declines.

Conclusions and Recommendations

This review has presented persuasive evidence that over-wintered stubbles, and the associated spring-sown crops, provide essential resources for farmland birds during the breeding and winter season. Indeed, it is arguable that the evidence available for this agri-environment prescription is the strongest support to date that such schemes benefit farmland birds, even to the extent of impacting their subsequent local population trends (Gillings *et al*. 2005). Despite this, however, there are still ways in which the existing ELS option might be adapted to improve its delivery for farmland birds. Firstly, the current prescription stipulates that over-wintered stubbles should be retained until the 15th February, after which it may be ploughed and sown. However, the prevailing perception is that the critical period during which farmland birds experience resource shortages is in late winter and early spring, when seed abundance is at its most depleted (Siriwardena and Anderson 2007). Thus, by permitting stubbles to be ploughed at this early date, stubble seed resources are not liable to be available to farmland birds during this crucial period. There is a strong argument, therefore, for extending the retention of stubbles well into March. Secondly, in the above review, we described the various management techniques that have been trialled to improve the value of stubble fields for farmland birds (Butler *et al*. 2005; Whittingham *et al*. 2006). These experiments showed that, in particular, topping of stubble swards to a height of 5cm was an effective management practice, resulting in increased use of stubble fields by granivorous birds, the suite of species that have demonstrated the most pronounced declines in agricultural landscapes (Butler *et al*. 2005). Therefore, a stipulation that encourages limited topping of stubble swards under the ELS prescriptions may be desirable. Note, however, that wholesale topping of stubble swards should not be advocated, because some important species, including Skylark and Grey Partridge, prefer foraging during the winter in relatively taller vegetation (Butler *et al*. 2005). Instead, the prescription should seek to promote heterogeneity of stubble heights (Butler *et al*. 2005). The option of scarification should be tested on light soils. Thirdly, a stipulation of the existing prescription is that over-wintered stubbles should receive a light surface cultivation (i.e. scarification) before the end of September to encourage weed germination and loosen any surface compaction. However, from the perspective of farmland birds, it is questionable whether encouraging germination this late in the year is advisable, because it is unlikely that germinated weeds will subsequently set seed. Therefore, such a management practice is likely to decrease the availability of winter seed food resources for granivorous farmland birds (R. Winspear *pers. comm.*). This is perhaps a good justification for revising this particular stipulation of the option. Finally, another stipulation of this agri-environment measure is that stubbles must be followed by a spring-sown crop. However, removing such a condition might encourage more fields to be left as summer fallows, which are know to be beneficial for a range of farmland birds (R. Winspear *pers. comm.*.).

EF7 – Beetle banks

The development of beetle banks was motivated by the aim of creating suitable overwintering sites for beneficial predatory invertebrates in arable crops (Thomas *et al*. 1992). Located in field centres, these habitat features represent a dispersal source from which predatory insects can rapidly colonise the cereal crops during the spring and summer, preying on cereal pests, particularly aphids. Beetle banks comprise low ridges, approximately 1.5 m wide, which are sown with a mixture of tussock-forming grasses, such as *Dactylis glomerata* and *Holcus lanatus* (Thomas *et al*. 2000). Despite farmland birds not being the intended beneficiaries of beetle banks, they nonetheless appear to provide resources for some species.

Breeding Season Resources

The dense, tall sward structure of beetle banks, although providing optimal overwintering conditions for a variety of predatory invertebrates, is not liable to be favoured as a nesting habitat by many farmland birds. Possible exceptions to this include the Grey Partridge (Potts 1986) and Skylark (Murray 2004).

Rather than offering suitable nesting habitat, beetle banks may provide greater foraging opportunities for some farmland bird species. Several empirical studies have demonstrated that these habitat features harbour high densities of polyphagous predators, notably beetles and spiders, both of which are key constituents in the diet of many farmland birds (Thomas *et al*. 1991; Thomas *et al*. 1992; Collins *et al*. 2003). Thomas *et al*. (2001) evaluated the merits of beetle banks from the perspective of resource provision for gamebirds, particularly Grey Partridge. The authors showed that beetle banks could maintain high densities of insect prey preferred by game chicks, almost equivalent to those documented in adjacent hedgerows and field boundaries, and suggested that they represented valuable additional resource to these species. However, despite the fact that beetle banks may represent rich foraging sites, there is relatively little indication that farmland birds exploit this resource to any great degree. For example, Stevens and Bradbury (2006) were unable to determine that either the Corn Bunting, Lapwing, Skylark or Yellow Wagtail responded positively to the provision of beetle banks during the appraisal of the Arable Stewardship Pilot scheme. Although it should be noted that Murray *et al*. (2002) showed that Skylarks (but not Yellowhammers) in East Leicestershire foraged more in beetle banks than expected based on their relative availability.

One characteristic of beetle banks that may restrict its value as a forging habitat for farmland birds is its dense, tussocky architecture. This vegetation structure is liable to be unattractive to some species for two reasons. Firstly, tall, dense swards reduced foraging efficiency both directly, through its effects on food detectability and accessibility (McCracken and Tallowin 2004), and indirectly, by hindering forager mobility (Butler and Gillings 2004). Secondly, some farmland birds appear to associate taller swards with greater predation risk, which restricts their use of this habitat. Murray *et al*. (2002) suggested that the aversion of Yellowhammers to beetle banks in their study was because the vegetation structure precluded them exploiting the abundant food resources.

Finally, beetle banks are known to be attractive nesting habitats for small mammals (Bence *et al.* 1999), and consequently, Boatman *et al.* (2000) surmised that they might also provide fruitful hunting grounds for Kestrel and Barn Owl.

Winter Season Resources

Collins *et al.* (2003) recorded invertebrate densities during winter in excess of 2000 individuals m^{-2} in some beetle banks. This represents a considerable concentration of potential food resources, and as such, it is likely to be exploited by at least some farmland bird species; however, thus far no studies have explicitly examined the winter usage of beetle banks by birds. In addition, Kestrel and Barn Owl are also liable to continue hunting over beetle banks during the winter period.

Conclusions and Recommendations

Beetle banks, in their current form, do not appear to be widely used by nesting and foraging farmland birds. Managing the vegetation structure of these habitat features either by mowing, scarification or the application of selective graminicides may be one option to increase their utility to birds. However, such a management regime would inevitably conflict with the original objective of the beetle bank, which is to provide optimal overwintering habitat for beneficial predatory invertebrates, and thus is not liable to be tenable. Where beetle banks are employed as nesting habitat by Grey Partridge, it is important that beetle banks are not contiguous with field boundaries. If beetle banks do adjoin field boundaries, it is likely that predators will be attracted to these linear habitat features, perhaps turning the beetle banks into an ecological trap (T. Morris *pers. comm.*).

EF8 – Skylark Plots

A predominant driver of the Skylark decline in Britain is thought to be the substitution of spring-sown crops with winter-sown alternatives (Donald and Vickery 2000). In addition to the associated loss of overwintered stubbles, this change has also reduced the suitability of arable crops as a breeding habitat. Autecological studies suggest that Skylarks preferentially nest in vegetation characterised by a height of less than 50cm (Donald 2004), but winter-sown crops frequently exceed this threshold height by the end of May. Consequently, this leads to an effective curtailment of the Skylark's reproductive season, such that only 1-2 broods can be completed, compared to the 3-4 broods that would ordinarily be undertaken in the presence of season-long suitable breeding habitat. Skylark plots seek to rectify this dearth of late-season breeding habitat by providing undrilled plots within the centre of conventional winter-sown wheat fields (Morris *et al.* 2004). There is encouraging evidence from large-scale replicated field trials that these plots provide essential resources not just for the target species, Skylark, but for a wider assemblage of farmland birds (Morris *et al.* 2007; Cook *et al.* 2007).

Breeding Season Resources

Morris *et al.* (2007) investigated the repercussions of skylark plots on the territory distribution and reproductive success of Skylarks in winter wheat fields. These authors showed that early in the breeding season, territory densities were broadly similar between conventional wheat fields and those containing skylark plots; however, as the season progressed, densities on the conventional wheat fields declined, whereas those with skylark plots maintained early-season densities (Morris *et al.* 2007). These findings are consistent with the observations of previous studies that beyond a particular vegetation height (approx. 50 cm), conventional winter wheat becomes an inappropriate breeding habitat for Skylarks (Jenny 1990; Wilson 1997). In contrast, fields incorporating skylark plots did not experience equivalent declines in territorial birds, which implies that modifying within-field crop structure in this manner creates suitable habitat for Skylarks, particularly late in the reproductive season (Morris *et al.* 2007). Morris *et al.* (2007) showed that wheat fields containing skylark plots held 40% more Skylark territories late in the breeding season than conventional wheat fields. Furthermore, patterns of nest density largely paralleled those of territory density (Morris *et al.* 2007).

The presence of skylark plots within winter wheat fields considerably influenced the productivity of breeding Skylarks (Morris *et al*. 2007). Clutch sizes in fields with skylark plots were significantly larger than those laid in conventional wheat crops (Morris *et al*. 2007). This finding, in conjunction with a non-significant trend for greater nest survival, resulted in breeding attempts in plot-containing fields producing, on average, an additional 0.5 chicks per attempt (Morris *et al*. 2007). The discrepancy between different field types was even more pronounced later in the breeding season, when nests laid in experimental fields yielded an extra 1.5 chicks per attempt relative to nests in conventional wheat fields.

Curiously, the benefits that skylark plots were initially envisaged as providing do not appear to underlie this higher breeding productivity (Morris *et al*. 2007). During the development of the prescription, it was anticipated that the provision of skylark plots might afford nesting opportunities for Skylarks throughout the breeding season. On the contrary, however, birds rarely used these sites for nesting, instead continuing to situate their nests with the tall sward of the winter wheat. It is generally unknown why Skylarks did not use these plots for nesting, although one plausible explanation is that they perceive such sparsely vegetated areas as being of high predation risk (Morris *et al*. 2007). Rather, the mechanism underlying the improved productivity appears to be related to the elevated food accessibility provided by these plots through the reproductive season (Morris *et al*. 2007). Skylark plots were used significantly more frequently by foraging individuals than expected according to their relative availability within the landscape (Morris *et al*. 2007). In watches where the ultimate destination of foraging flights was known, 17% of adults went to skylark plots, which represented only 0.42% of the study area (Morris *et al*. 2007). In contrast, skylark plots had inconsistent effects on the abundances of arable weeds and invertebrates within winter wheat fields, which suggests that augmented food resources were not responsible for the observed increase in productivity (Morris *et al*. 2007).

Cook *et al*. (2007) examined the joint influence of skylark plots and managed field margins on the territory distribution and abundance on an array of farmland bird species. Interestingly, most species demonstrated a synergistic effect of both management regimes, such that the combination of both skylark plots *and* field margins recorded the greatest densities of birds (Cook *et al*. 2007). For example, fields characterised by both management prescriptions held fivefold greater densities of territorial Yellow Wagtails than conventional winter wheat fields, or either option in isolation. Furthermore, the territorial density of species with Biodiversity Action Plans was 2.8 times greater on fields with both options compared to conventional winter wheat fields (Cook *et al*. 2007). Cook *et al*. (2007) suggested that it is the combination of both abundant (field margins) and accessible (skylark plots) food resources that probably accounts for the appeal of the dual management prescriptions to many farmland birds.

Paralleling the patterns apparent in other species assemblages, Skylarks also exhibited the greatest densities in fields with both skylark plots and field margins (Cook *et al*. 2007). However, in spite of pronounced densities of Skylark, these fields were actually characterised by the lowest breeding productivity per unit area of any field type, including that of conventional wheat crops (Cook *et al*. 2007). This is because nests located in fields with managed margins experienced exceptional levels of predation; for example, the rate of predation in fields with both management options was 89%, almost double that of fields lacking such options. Currently, the precise reasons as to why the magnitude of nest predation in these fields was quite so considerable is not clear, but Cook *et al*. (2007) suggested that these habitat features results in a field becoming a predator trap. Although a somewhat discouraging finding, some solace can be taken from the fact that nest predation varies as a function of distance from the field margin, such that nests further into the field centre suffer less pronounced rates of predation than those more proximate to the boundary (Cook *et al*. 2007). Therefore, it may be possible to negate the detrimental effect of increased predation by situating skylark some threshold distance from field boundaries, although it should be noted that the positioning of skylark plots may not dictate the within-field distribution of Skylark nests (Cook *et al*. 2007). The recommendation made from this study is that skylark plots should be deployed in large fields where they can be at least 70-80m from the margin. Were such a compromise to prove effective, then it would be possible to retain the broader benefits of the joint prescriptions on a wider array of farmland birds, while also fulfilling the initial objective of the skylark plot prescription of improving Skylark reproductive success in winter wheat crops (Cook *et al*. 2007).

Winter Season Resources

Very little is known about the extent to which skylark plots provide resources for farmland bird species during the winter period, although it is probably fair to say that few benefits would be anticipated. If nothing else, weed seed availability may be enhanced on those stubbles where plots had been present during the summer period compared to those stubbles where they were absent.

Conclusions and Recommendations

Early indications are that the incorporation of skylark plots into otherwise conventionally managed winter wheat crops shows promising potential for delivering breeding season resources to the target species, Skylark, but also a broader array of farmland birds. However, further investigations are necessary into the effects of field margins and skylark plots on rates of nest predation in a broader range of species, and possible management solutions to this problem. Two other recommendations can be advanced for skylark plots. Firstly, initial feedback from farmers suggests that they find the implementation of skylark plots via the cessation of drilling to be difficult, and instead, would be more in favour of spraying off the plots (R Winspear *pers. comm.*.). Trials are currently underway as to the efficacy of creating skylark plots using this method. Preliminary results suggest similar benefits for Skylarks as long as the plots are sprayed out before the end of the calendar year (R. Winspear *pers. comm.* RSPB Farmland Advisor). Secondly, examination of initial agri-environment uptake statistics suggests that skylark plots are being implemented at too low a density within fields to have a optimal effect on resident farmland birds (R. Winspear *pers. comm.*). There is a need to encourage farmers to implement skylark plots at a density of 2 per hectare, the density at which they are most effective. Part of this could simply involve revising the stipulation in the ELS handbook from '…creating no more than two plots per hectare' to '…creating two plots per hectare' (R. Winspear *pers comm.*.).

EF9 – Conservation headlands in cereal fields
EF10 – Conservation headlands in cereal fields with no fertilisers or manure

Grey Partridges have decreased steeply on British farmland in recent decades. The demographic mechanism thought to underlie this decline is a reduction in chick survival, precipitated by decreased availability of dietary invertebrates through agricultural pesticide application. The Game Conservancy Trust (GCT) pioneered conservation headlands in Britain specifically to combat the declining populations of Grey Partridge and other game birds. By providing a cropped margin (6-24m) at the boundary of cereal fields that receives no inputs of insecticide and only restricted application of selective herbicides and fungicides, it was anticipated that these areas would offer suitable foraging areas for Grey Partridge chicks. Conservation headlands have been available as options in different agri-environment schemes (i.e. CSS and ESA) for a number of years, and the biodiversity benefits have been widely evaluated. There is persuasive evidence that they provide key resources during the summer not only for Grey Partridges and farmland birds, but an array of other taxa (Sotherton 1990; Stevens and Bradbury 2006; Frampton and Dorne 2007).

Breeding Season Resources

Whether conservation headlands provide nesting resources for farmland birds is not a topic that has received a great deal of attention. However, the management regime to which cereals are subject does not radically alter the structure of the crop itself, and consequently, it is not anticipated that conservation headlands will offer a nesting habitat any more desirable than that provided by conventional cereal crops. Instead, conservation headlands are more likely to afford important foraging opportunities for farmland birds. The most convincing evidence of this comes from an experimental study of the Grey Partridge. Rands (1985) contrasted the breeding productivity of this species in cereal fields with and without conservation headlands, and demonstrated that mean brood size, and ultimately chick survival rates, was higher where pesticide restrictions had been imposed. The author attributed greater chick mortality in fields lacking conservation headlands to diminished food availability, because lower densities of important chick-food invertebrates (e.g. Heteroptera, Chrysomelidae and Curculionidae) were documented in these fields (Rands 1985). These findings have been replicated both in other populations of Grey Partridge, and in other game birds (e.g. Pheasant, Chiverton 1999).

Further support for the importance of conservation headlands to farmland birds is yielded from investigations of habitat use. For example, Stevens and Bradbury (2006) showed that Whitethroat, Greenfinch and Yellowhammer were positively associated with boundary habitats next to which there had been restricted pesticide use (i.e. conservation headland or reduced herbicide use; but see Green *et al*. 1994). Furthermore, de Snoo *et al*. (1994) noted that Yellow Wagtail, but not Skylark, utilised unsprayed crop margins significantly more frequently than sprayed margins. As is the case with the Grey Partridge, the greater use of conservation headlands than conventionally managed crops is probably related to disparate patterns of food abundance. Several other empirical studies have demonstrated that important dietary invertebrates are more prevalent in conservation headlands than conventional crops (reviewed in Frampton and Dorne 2007). Furthermore, Critchley *et al*. (2004) showed that conservation headlands were characterised by a greater abundance of key bird food plants, including *Cirsium arvense* and *Holcus lanatus*, than normally cropped cereal headlands. Finally, Tew *et al*. (1992) demonstrated that Wood Mice preferentially selected conservation headlands in which to forage compared to unsprayed headlands. These authors suggested that conservation headlands might represent productive foraging habitats for Barn Owl and Kestrel. This is questionable, however, because these predators generally avoid foraging in cereal crops, as its vegetation structure is not conducive to successful hunting (see appendix 2).

Winter Season Resources

ELS prescriptions permit conservation headlands to be harvested at the same time as the rest of the arable crop, which means these options do not provide for farmland birds during the winter. However, within HLS, there is an arable option that stipulates that conservation headlands should remain unharvested. It is beyond the remit of this current review to assess the potential value of unharvested conservation headlands for farmland birds during the winter.

Conclusions and Recommendations

Data from empirical studies suggests that conservation headlands provide key resources for farmland birds. This is certainly true for game birds and though the evidence is less quantitative, non-game species are also likely to benefit, during the breeding season. The only recommendation that we would make for this option is that many of the herbicides previously allowed under CSS/ESA have been discontinued, and there is a need for a review of the new chemicals available to update the list (R. Winspear *pers. comm.*.).

EF11 – 6m uncropped, cultivated margins on arable land

Uncropped margins comprise a 6 m strip of land adjacent to arable crops where vegetation is permitted to regenerate naturally, without the addition of any sown mixtures (Vickery *et al*. 2002). Under current ELS stipulations, these margins must receive light cultivation annually (Anon 2005), a management practice that is designed to encourage the establishment of annual arable flowers, such as *Adonis annua* and *Centaurea cyanus* (Vickery *et al*. 2002), while also precluding the development of perennial weeds. Although the intended beneficiaries of uncropped margins are rare arable weeds, it is anticipated that these options will afford rich foraging habitats for an array of farmland bird, particularly during the breeding season (Vickery *et al*. 2002).

Breeding season resources

Empirical data suggesting that uncropped margins are of utility to species within the farmland bird index derives from the Arable Stewardship Pilot Scheme. Stevens and Bradbury (2006) demonstrated that the presence of an uncropped strip at the boundary of a field had a positive influence of the occurrence of Reed Buntings. Surprisingly, however, no other species considered by this study exhibited an equivalent response to these margins (Stevens and Bradbury 2006). The authors attributed this association of the Reed Bunting to the provision of abundant foraging opportunities within the uncropped margin, both in terms of the availability of seed and invertebrate resources (Steven and Bradbury 2006). This suggestion is supported by the findings of several studies that have contrasted the plant and invertebrate communities of different types of field margin. For example, Critchley *et al*. (2004) showed that uncropped margins were characterised by the greatest number of annual weeds, including *Sonchus asper*, *Polygonum aviculare*, and *Poa annua*, all of whose seeds are fed upon by granivorous birds (Wilson *et al*. 1999). Furthermore, it has also been demonstrated that uncropped strips harbour higher abundances of bumblebees, butterflies, spiders, bugs, and sawflies than conventional crop margins (ADAS 2001; Pywell *et al*. 2007).

Browne and Aebischer (2004) reviewed management options that may facilitate the recovery of the British Turtle Dove population, suggesting that uncropped, cultivated margins may provide this species with weed-rich foraging habitats. Unusually amongst farmland birds, the diet of both adult and nestling doves during the breeding season is constituted almost exclusively by seeds, and it has been suggested that reductions in the availability of arable weeds may be one of the principle drivers of decline in this species. Furthermore, Wilson *et al*. (2007) also proposed that uncropped margins may be a important source of nestling food for the Corn Bunting.

Winter season resources

Relatively little is known about the potential foraging opportunities afforded by uncropped, cultivate margins for farmland birds during the winter period. Presumably, as these strips are typically characterised by a diverse annual weed fauna, there will be a rich seed bank that granivorous birds can exploit during the winter months.

Conclusions and Recommendations

Several studies have shown that invertebrates and arable weeds are relatively abundant on uncropped margins, certainly more so than conventional crop boundaries (ADAS 2001; Critchley *et al*. 2004; Pywell *et al* 2007). In addition, these habitat features are often characterised by sparse vegetation cover and a high area of bare soil (Meek *et al*. 2002), which thus affords greater access to these food resources. With this combination of both food availability and accessibility, it is reasonable to predict that uncropped margins would be considerably exploited by a range of farmland birds, although they tend to be restricted to light soils. As for conservation headlands, we have no specific recommendations concerning this option.

Options to Encourage a Range of Crop Types

A range of studies have suggested that increasing habitat heterogeneity within farmland, at the local and landscape scale, could be a key tool in population recovery for wildlife in general and birds in particular (e.g. Robinson *et al*. 2001; Atkinson *et al*. 2002; Benton *et al*. 2003). The following options EG1-EG5 are designed to do just this, and in a generic sense, they are all likely to enhance biodiversity.

EG1 – Undersown spring cereals

Undersowing spring cereals is a traditional rotational cropping practice whereby a spring crop, such as barley, is simultaneously sown with a grass/legume mix (mostly *Lolium* spp. and clover *Trifolium* *repens*). Following the harvest of the cereal crop, the field is subject to no further cultivation, and a grass ley is permitted to develop. Under current ELS stipulations, grass leys must then remain undisturbed at least until the end of the following summer, although livestock may graze them (Anon 2005). With the intensification of agriculture in Britain, mixed farming systems, including the use of undersown spring cereals, have increasingly been superceded by greater specialisation, either solely arable or pastoral agriculture. This agri-environment prescription seeks to reinstate mixed farming practices in Britain by encouraging the creation of rotational grass leys within arable-dominated areas.

Breeding Season Resources

Perhaps the most persuasive evidence that undersown spring cereals are important in maintenance of certain farmland bird populations derives from a long-term study of the Grey Partridge. Aebischer and Potts (1998) contrasted the change in densities of this species between 1970-1994 on 5 farms in Sussex, one of which retained a traditional ley farming system (undersown spring cereals and rotational grass leys), while the others adopted more intensive agricultural regimes. The authors showed that whereas partridge population densities fell steeply (72%) on the intensive farms, they remained virtually identical on the farm characterised by more traditional practices (Aebischer and Potts 1998).

Although improved overwinter survival mediated by the provision of suitable cereal stubbles may partially explain this difference, another potential reason is that undersown spring cereals, and the grass leys that they subsequently become, are rich foraging areas, particularly for chick-food invertebrates. For example, Aebischer (1990) showed at the same Sussex study site, that the density of graminivorous Sawfly larvae (Symphyta), which are an important dietary component of the chicks of several farmland birds, was positively associated with the area of undersown spring cereals in the preceding year. Sawfly pupae overwintering in the soil are known to be particularly vulnerable to mortality through post-harvest cultivation (Barker *et al*. 1999). As undersown spring stubbles remain undisturbed, it was suggested that more sawfly larvae survive the winter in these crop types, and are thus available as prey for the offspring of farmland birds in the following spring (Aebischer 1990).

Undersown spring cereals are also known to benefit other farmland birds. For example, Wakeham-Dawson *et al*. (1998) found that Skylarks occurred at greatest densities in undersown spring cereals on the South Downs. Furthermore, in the same area, Aebischer and Ward (1997) showed that densities of Corn Bunting were highest in areas of mixed farming, characterised by undersown spring barley and rotational grass. Similar to the Grey Partridge, the habitat-specific densities in the Corn Bunting appear to reflect underlying differences in food abundance, because the abundance of this species was positively related with the number of caterpillars (Lepidoptera/ Symphyta larvae) in cereal crops, which were most prevalent in undersown spring cereals (Aebischer and Ward 1997).

It should noted that whereas sawfly larvae appear to profit from the provision of undersown spring cereals, these crops do not similarly benefit all farmland bird prey. For example, a recent study, conducted under the auspices of the Arable Stewardship Pilot Scheme (ASPS), demonstrated that the abundance and community composition of both Hemiptera and Carabidae differed little between undersown spring cereals and conventional (i.e. not undersown) spring cereals (ADAS 2001). Furthermore, from the perspective of predominant granivores, undersown spring cereals are not liable to be particularly rich foraging sites, because the sown grasses and legumes generally prevent the establishment of a diverse arable plant flora, implying that dietary weed seed are liable to be relatively impoverished within these fields (Critchley *et al*. 2004). Moreover, the accessibility and detectibility of weed seeds is also liable to reduced where spring cereals are undersown (A. Evans *et al*. 2004).

Finally, although undersown spring cereals are a management practice traditionally associated with arable farming, Defra (2007) recently experimented with its use in regions of intensive grassland agriculture as a field margin treatment to improve these areas for farmland birds. These authors demonstrated that during summer, small insectivorous birds and finches and buntings used these undersown margins proportionately more than they did conventional grass margins (Defra 2007). In contrast, large insectivores exploited undersown margins to an equivalent extent as other grass margins (Defra 2007). As undersown margins were characterised by similar invertebrate densities as the alternative margins (except bumblebees and butterflies), Defra (2007) suggested that the observed response to the disparate management treatments reflects not differences in food availability, but differences in food accessibility. Specifically, it was posited that undersown margins exhibited a more patchy sward, which facilitated access of farmland birds to dietary invertebrate prey (Defra 2007).

Winter Season Resources

Moorcroft *et al*. (2002) investigated the use of different types of stubble by wintering farmland birds. With the exception of Woodpigeon, no species preferentially selected undersown wheat stubbles, all other species occupying intensive barley stubbles to a greater extent (Moorcroft *et al*. 2002). This finding is curious, because the undersown wheat stubbles were characterised by equivalent densities of seeds to intensive barley stubbles (Moorcroft *et al*. 2002), thus suggesting that this preference cannot be dictated solely by food abundance. Rather, Moorcroft *et al*. (2002) postulated that this differential use of stubble types may be an issue of accessibility to food resources. Specifically, undersowing engenders a considerable reduction in the amount of bare earth within stubbles, which may have diminished the foraging efficiency, and subsequent appeal of undersown stubbles to farmland birds (Moorcroft *et al*. 2002). In contrast, the greater occupancy of undersown stubble fields by Woodpigeon is liable to be due to its preference for grazing on clover during the winter period (Moorcroft *et al*. 2002). Finally, Vickery *et al*. (2007) showed that small insectivorous farmland birds used undersown spring cereal margins to a greater extent than conventional grass margins in pastoral-dominated areas of England.

Conclusions and Recommendations

This review suggests that undersown spring cereals provide important breeding and winter season resources for species of conservation concern in Britain. Currently, this prescription stipulates that cereal crops should not be harvested prior to the 1st July, but reproductive attempts of some farmland birds conducted within these cereals can extend to the end of July/beginning of August, and such an early harvest date may jeopardise the completion of these attempts. Therefore, it would be wise to consider an extension of the no-harvesting period to the 15th July or later. Furthermore, another recommendation is that both the cereal crop and undersown component should be sown at the same time to reduce the chances of disruption of ground-nesting birds.

EG4 – Cereals for whole crop silage followed by over-wintered stubble

In pastoral regions of lowland England, maize accounts for the majority of arable cultivation, where it is grown as a substitute to grass silage for cattle forage. However, maize appears to be of relatively limited value as a nesting or foraging habitat for most farmland birds. This option seeks to encourage the replacement of maize cultivation with cereal crops, specifically wheat and barley, which provide essential resources for these species during both summer and winter.

Breeding Season Resources

The potential benefits of cereal-based whole crop silages as nesting habitat for farmland birds in pastoral landscapes has not been explicitly tested by any study, but it is likely to afford nesting opportunities for a range of different species. The use of spring-sown cereals, in particular, would provide favourable nesting conditions for a suite of species that prefer short sward heights, including Lapwing, Skylark, and Yellow Wagtail (see appendix 2).

Mortimer *et al*. (2007) investigated the extent to which farmland birds utilised different fodder crops in livestock-dominated regions of England, comparing fields of winter wheat, high- and low-input spring barley, maize and short-term grass leys. In summer, seed-eaters (finches, sparrows, buntings, and Skylarks) were strongly associated with the cereal crops, but made comparatively little use of either maize or grass leys (Mortimer *et al*. 2007). A similar pattern of summer habitat preference was also demonstrated by two red-listed bunting species (Yellowhammer and Reed Bunting, Mortimer *et al*. 2007). In contrast, insectivorous farmland birds (wagtails, Dunnock, Robin, Wren, Whitethroat and Meadow Pipit) made relatively greater use of maize crops, especially early in the summer, prior to the crop being sown and during its initial growth phase (Peach *et al*. 2007). Hirudines foraged preferentially over barley fields, with proportionately less use of grass, and virtually no use of maize (Mortimer *et al*. 2007).

The habitat preferences of farmland birds appear to reflect the distribution of food resources between different fodder crop types. Botanical assessments conducted by Mortimer *et al*. (2007) showed that some plants important in the diet of birds, specifically annual meadow grass (*Poa annua*) and chickweed (*Stellaria media*), but not field pansy (*Viola arvensis*), were significantly more abundant in winter wheat and spring barley than maize during the summer. Furthermore, important dietary invertebrates, including Coleoptera, Diptera, Hymenoptera and Hemiptera, also occurred at greater densities in cereal crops in contrast to maize.

Winter Season Resources

Granivorous birds used over-wintered barley stubbles almost to the exclusion of other crop types during the winter period (Mortimer *et al*. 2007). This strong association was attributed to the fact that barley develops a weedy stubble, characterised by high densities of broad-leaved plants and unsown grasses, whose seeds are an important food resource for farmland birds (Mortimer *et al*. 2007). A preference for barley stubble, over other stubble types has been recorded in a number of other studies (e.g. Moorcroft et al 2002; Vickery et al 2005). Similarly, insectivores demonstrated analogous patterns of habitat preference to seed-eating species during the winter period, but thrushes largely avoided barley stubbles, foraging instead on worm-rich grasslands (Mortimer *et al*. 2007).

Conclusions and Recommendations

The use of cereal-based whole crop silage as an alternative to conventional grass and maize fodder crops potentially affords important nesting and foraging resources for a range of farmland bird occupying primarily grassland-dominated landscapes. In particular, maximal benefits are liable to be accrued where spring-sown barley is cultivated as opposed to winter wheat or maize, because weedy barley stubbles have been shown to be valuable foraging habitats for these species. However, as for winter stubbles, this prescription may be ploughed after the 15th February, which is prior to the period when natural seed abundance is at its most depleted (late February-March; Siriwardena and Anderson 2007). An important added benefit could be gained by extending the retention of stubbles well into March. Furthermore, herbicides can be applied to over-wintered stubbles between 1st February and the 31st March, which curtails the growth of important broad-leaved weeds and unsown grasses. Implementing more stringent herbicide restrictions within the framework of this ELS prescription would clearly benefit several declining farmland birds.

EG5 – Brassica fodder crops followed by over-wintered stubbles

Brassica fodder crops, including rape, kale and turnips, are sometimes grown in pastoral agricultural areas as an alternative forage for livestock during the winter period (Anon 2005). The crops are grazed *in situ*, after which the field is retained as an over-wintered stubble until at least the middle of February (Anon 2005). This is a traditional cropping practice that was widely used, but that has fallen out of favour with farmers, largely superceded by the cultivation of silage and maize fodder crops. For example, the acreage of fodder brassicas in Scotland declined by 81% between 1965-2000, and now constitutes only 2.6% of the cropped area (Hancock and Wilson 2003). This option serves to promote the use of brassica crops as an alternative to silage, thus contributing to the establishment of a mixed farming mosaic with all the attendant benefits that this entails for farmland birds (Anon 2005).

Breeding Season Resources

There is little published work on the potential nesting or foraging benefits afforded by brassica fodder crops for farmland birds during the breeding season. Although wild bird crops also often comprise brassica-like crops, such as kale, the kale is permitted to set seed, in its second-year, so differences in use are confounded by differences in the availability of the crop seed. Some indication of the potential value of fodder kale for foraging insectivorous birds comes from the study of Moreby and Southway (2002), who showed that wild bird crops, much of which were kale-based, held greater densities of key invertebrate food taxa, including Araneae, Heteroptera and Carabidae, than conventional crops. The value of crops like kale for insectivorous birds has been demonstrated by a number of other studies (e.g. Henderson et al 2004; Defra 2007).

Winter Season Resources

Evidence to suggest that farmland birds profit from the provision of brassica fodder crops and fodder stubbles during the winter derives from a number of studies on habitat associations. Henderson *et al.* (2004) documented that first-year kale, prior to its seeding seed, harboured relatively high densities of Dunnock, Song Thrush and Blackbird, three insectivores that are declining within the agricultural environment. In addition, these authors also showed that fodder rape crops were preferred winter foraging habitats for four FaBI granivorous passerines – Tree Sparrow, Goldfinch, Linnet and Yellowhammer – while stubble turnips was in the top three ranking crops for Skylark (Henderson *et al.* 2004). Hancock and Wilson (2003) demonstrated that fodder crops and stubbles in Scotland were characterised by the highest densities and species diversity of seed-eating passerines. Specifically, these crops harboured 2.6 times more of all seed-eating passerines than other cereal stubbles (barley, oat and wheat), while species of conservation concern, including Skylark, Tree Sparrow, Twite, Reed Bunting and Corn Bunting, were 1.3-3 fold more abundant on fodder crops and stubbles than conventional cereal stubbles. In a related study, Grey Partridge were also shown to occur at the greatest densities in fodder crop fields throughout the winter period in Scotland, while in regression models, field occupancy was strongly predicted by the availability of fodder crops (Hancock and Wilson 2002).

The primary benefit of fodder crops and stubbles for wintering farmland birds is that they are generally accompanied by a dense and diverse growth of weeds, which therefore affords an abundance of seeds. For example, Hancock and Wilson (2003) noted 35 genera of broad-leaved weeds in fodder crops, including the seven that are regarded of most significance to granivorous farmland birds (Wilson *et al.* 1999). The reason that fodder crops tend to quite so weedy is because they are broad-leaved, and as such, are vulnerable to herbicides developed to target broad-leaved weeds (Buckingham 2007). In addition, farmers often tolerate weeds because fodder brassicas yield well in their presence (Hancock and Wilson 2003). Hancock and Wilson (2003) suggested that a further benefit of fodder crops may be that if they are managed by strip grazing, the gradual movement of animals through the crop would regularly reveal new seed sources, which would be readily accessible to farmland birds. Finally, less is known about the invertebrate populations harboured by fodder crops and stubbles during the winter period, although Henderson *et al.* (2004) suggested that the frequent usage of first-year kale by three insectivorous species (see above) was perhaps demonstrative of the rich invertebrate populations that it supported.

Conclusions and Recommendations

The above review of brassica fodder crops and stubbles suggests that this option delivers important resources for farmland birds, particularly during the winter period. The major problem with the current prescription is that, like all over-wintered stubble agri-environment options, stubbles must only be retained until the middle of February. Food is most scarce, however, in late winter, from the end of February into March, and important benefits for birds may be obtained by extending the period of obligatory retention until mid March.

Options for Lowland Grassland and the Uplands

EK2 – Permanent grassland with low inputs
EK3 – Permanent grassland with very low inputs
EL2 – Manage permanent in-bye grassland with low inputs
EL3 – Manage in-bye pasture and meadows with very low inputs

The latter half of the 20th century witnessed considerable changes to grassland management regimes, characterised by an increased use of nitrogenous fertilisers, enhanced stocking densities, a switch from hay to silage making, and reseeding of grassland (Vickery *et al*. 2001). These changes have profoundly influenced the structure and composition of agricultural grasslands, transforming traditional species-rich hayfields and unimproved grazed fields to uniform pastures dominated by competitive rye grasses *Lolium* spp (Vickery *et al*. 2001). These changes have also coincided with marked reductions in the populations of farmland birds associated with agricultural grasslands, which implies that they may have detrimentally impacted the nesting/foraging opportunities available to these species. The agri-environment options described here attempt to encourage the re-extensification of grassland management by limiting the application of fertilisers, prohibiting re-seeding, and preventing harrowing or rolling during peak periods of the bird breeding season.

Breeding Season Resources

Whether these low-input grassland management prescriptions deliver measurable benefits for farmland birds is unclear, because there are as yet no published experimental studies that explicitly evaluate these options in detail. Defra-funded research is currently underway that will provide some insights into the advantages of extensifying agricultural grasslands, but this is not expected to report until 2009 (BD1454). In the absence of experimental investigations, our perceptions of the probable benefits of these options derive largely from correlative studies of bird-habitat associations, and autecological studies of individual species.

Some farmland birds exhibit a preference for nesting in grassland with short swards. For example, Milsom *et al*. (2000) showed that the optimal sward height for Lapwings on coastal grazing marshes was between 30-50 mm, while Toepfer and Stubbe (2001) found that the preferred vegetation height for a population of nesting Skylarks in Germany was 15-60 mm. The application of nitrogenous fertilisers to agricultural grasslands, however, promotes vigorous growth of a dense sward, which may provide inappropriate nesting conditions for many of these species (Vickery *et al*. 2001). Placing restrictions on fertiliser use, particularly in the more stringent prescriptions (EK3, EL3), may facilitate the development of more favourable sward structures for these birds. Moreover, another benefit potentially afforded by this prescription for ground-nesting birds is that rolling and harrowing operations are prohibited between 1st April and 31st May (EL2, EK2) or 30th June (EK3, EL3). Agricultural operations can constitute an important source of nest failure during the reproductive season (e.g. Lapwing, Linsley 1999; Yellow Wagtail, Wilson 1991), and this stipulation allows a window of opportunity during which farmland birds may safely undertake breeding attempts.

A number of studies have examined patterns of grassland habitat use in relation to the intensity of management, specifically the extent of fertiliser application. For example, Atkinson *et al*. (2005) showed that the response of farmland birds to increasing fertiliser loads varied between species, with four (Carrion Crow, Rook, Blackbird and Woodpigeon), two (House Martin, Skylark), and six species (Jackdaw, Magpie, Starling, Swift, Swallow, and Robin) demonstrating positive, negative and no responses to high fertiliser use respectively. In another study, Buckingham *et al*. (2006) documented fewer associations between fertiliser input and field use by birds, although there was a negative relationship for obligate seedeaters (e.g. Linnet) during summer. This scarcity of observed relationships was attributed not to the fact that fertiliser use is unimportant in dictating the distribution of farmland birds in grasslands, but because they were masked by more influential grazing effects (Buckingham *et al*. 2006). In reality, therefore, the findings of these correlative studies are inconsistent and equivocal, and do not readily permit generalisations to be made regarding the possible consequences of reduction in fertiliser use on farmland birds.

Recent research has demonstrated that sward height is an important determinant of habitat selection in farmland birds foraging in agricultural grasslands (Devereux *et al*. 2004; Atkinson *et al*. 2005; Buckingham *et al*. 2006). For example, Devereux *et al*. (2004) showed that the foraging rates of Lapwing chicks declined with increasing sward height. As surface invertebrate abundance did not vary between long and short swards, the authors attributed this finding to greater sward heights either limiting chick foraging mobility or food accessibility (Devereux *et al*. 2004). Similarly, in the same study, Devereux *et al*. (2004) also showed that Starlings captured 33% more prey items on short sward than long sward grass. Starling intake rates were equivalent across the different sward heights, and instead, this finding was a reflection of the increased amount of time spent actively foraging on the shorter swards (Devereux *et al*. 2004). These findings suggest that a reduction in the application of nitrogenous fertiliser to grassland, resulting in a shorter, less vigorous sward, may benefit some farmland birds through the provision of additional suitable foraging habitats.

The final important mechanism by which low-input grassland options might affect farmland birds is by modifying their invertebrate and plant food availability. Recently, MacDonald (2006) reviewed the responses of farmland invertebrate and plant communities to the application of fertiliser. Increased fertiliser use tends to diminish the botanical species richness of agricultural grasslands, which in turn may reduce the seed availability for granivorous bird species, including the Linnet and Turtle Dove (MacDonald 2006). In contrast, the responses of invertebrates to the use of fertiliser were more inconsistent, varying according to their taxonomic status and life-history characteristics. For example, craneflies (Tipulidae: Diptera), leafhoppers (Auchenorrhycha), and true bugs (Heteroptera) appear to benefit from the increased organic and nutritive value of swards following the application of fertiliser (MacDonald 2006). On the other hand, beetles (Coleoptera), butterflies and moths (Lepidoptera), and grasshoppers (Orthoptera) are often adversely affected by use of fertiliser, because the loss of botanical diversity leads to the disappearance to suitable host plants, while the dense sward structure provides an inappropriate microclimate for the persistence of these species (MacDonald 2006). Therefore, whether a particular bird species is likely to be beneficially or deleteriously impacted by fertiliser-induced changes in the grassland insect assemblage is dependent on its specific invertebrate prey preferences. Atkinson *et al*. (2005) showed that foliar invertebrates were particularly susceptible to the application of high fertiliser loads, and suggested that the disappearance of these arthropods from the agricultural environment might underlie the decline of bird species for which they represent an important dietary resource, including the Whinchat and Red-backed Shrike.

Winter season resources

In addition to examining patterns of summer habitat selection, Atkinson *et al*. (2005) also evaluated the use of agricultural grasslands by farmland birds during winter. The authors showed that the occupancy of four soil invertebrate feeders (Carrion Crow, Rook, Jackdaw and Starling) and three foliar invertebrate feeders (Robin, Meadow Pipit and Pied Wagtail) was positively associated with increasing fertiliser application in grasslands of Devon and Buckinghamshire (Atkinson *et al*. 2005). In contrast, only one species, the Magpie, was characterised by a negative relationship with increased fertiliser use in this study (Atkinson *et al*. 2005). Similarly, Barnett *et al*. (2004) demonstrated that the same guild of soil invertebrate feeders was more numerous on improved grassland than unimproved grassland. There is some evidence that the distributional patterns highlighted by these studies are mediated by differences in food abundance. For example, soil invertebrates were more prevalent in intensively than extensively managed fields in Devon (Atkinson *et al*. 2005). Furthermore, Tucker (1992) noted that moderate (but not large) applications of organic fertiliser (farmyard manure) often benefit soil invertebrates, particularly earthworms, and posited that this may elucidate the enhanced use of frequently manured grass fields by Lapwing, Starling, Fieldfare and Redwing in his study. In general, the response to reduced fertiliser in grassland seems to vary between species and whilst some species such as the ground-feeding Carrion Crow and Rook can clearly tolerate relatively high levels of fertiliser use, this is almost certainly detrimental for other species that feed on surface- or sward-dwelling invertebrates.

Conclusions and Recommendations

In the above review, we have summarised the potential benefits that farmland birds might accrue from the implementation of low-input grassland agri-environment options, particularly mediated through the reduction in fertiliser application. In general, our understanding of resource requirements in grassland is relatively poor compared to arable system and so assessing the delivery of these options is difficult. However, in options EK2 and EL2, although the permitted levels of nitrogen input (100kg N/ha/year) are relatively limited, these are still sufficiently high to damage semi-natural plant communities, thereby reducing both botanical and invertebrate species richness of grassland fields (Buckingham 2007). The more stringent fertiliser restrictions imposed under options EK3 and EL3 have more potential to deliver foraging opportunities for farmland birds. Furthermore, the period during which mowing, harrowing and rolling is prohibited extends from 1st April – 31st May in options EK2 and EL2, but these dates do not encompass the full extent of the ground-nesting bird breeding season (Buckingham 2007). Skylarks, for example, can continue nesting into the middle of August (Donald 2004). Even the obligatory period (1st April-30th June) during which farming operations are prohibited in the more stringent prescriptions (EK3 and EL3) is insufficient in length to cover full breeding season of nesting birds. Considerable benefits could be accrued for ground nesting species by extending the period of exclusion of farming operations to encompass the majority of the breeding season of farmland birds. Finally, these options do not include any restrictions on grazing pressure. Although soil invertebrate feeders may benefit from the provision of short swards, birds that find food in the sward, which include those species that are of most conservation concern in Britain, require mosaics of various sward lengths, a structure that is not liable to develop under pronounced grazing pressure (Buckingham 2007). Grazing restrictions are included in certain HLS prescriptions, and it is these, rather than the above ELS options, that are most likely to afford significant benefits for farmland birds.

EK4 – Management of rush pastures (outside the LFA)
EL4 – Management of rush pastures (LFA land)

Rush pastures occur on poorly-draining, acidic soil types and are predominated by *Juncus* spp. The agri-environment options described here extend the EK2/EL2 options to provide rotational rush control for these grasslands. Rushes should be cut on an annual basis, but no more than one third of the area should be cut in any one year. This cut should then be followed either by aftermath grazing, or a second cut within 8 weeks. Cutting is prohibited between 1st April – 1st August to prevent the destruction of breeding attempts by machinery.

Breeding season resources

The use of rush pasture during the breeding season has received particular attention in relation to the suite of upland-breeding waders, including the Oystercatcher, Lapwing, Snipe, Curlew and Redshank. Small (2002) examined how variation in the extent of rush cover influenced the patterns of field occupancy in these species in the Pennine Dales ESA, and demonstrated that the strongest positive association with rushes was shown by the Snipe. This corroborates the findings of previous studies, which showed that Snipe select rush tussocks both as cover and as nest sites (Mason and MacDonald 1976; Gibbons *et al*. 1993). In this study, Snipe densities were highest on fields characterised by >10% cover of rushes, while significantly smaller densities occurred on fields with 1-10% rush cover, and no rush cover (Small 2002). In contrast, the other waders in this group appeared to demonstrate a non-linear relationship with rush cover. Intermediate rush cover (1-10%) was associated with elevated breeding densities of some species (Curlew, Redshank), but beyond a particular threshold cover (approx. 10%), rushes appeared to have a negative influence on the occurrence of most waders (Lapwing, Redshank, Oystercatcher; Small 2002). This agri-environment option was developed to ensure that rushes remain intermediate in their extent Brickle and Peach (2004) demonstrated that

Reed Bunting preferentially located their nests and foraged in rank, emergent vegetation, and suggested that managed rush pasture may also provide appropriate breeding and feeding habitat for this species.

Winter season resources

There is a dearth of information regarding the benefits provided by these agri-environment prescriptions for farmland birds during the winter.

Conclusions and Recommendations

Sensitive management of rush pasture may provide measurable benefits for certain farmland bird species, including the guild of wet grassland breeding waders (e.g. Snipe, Lapwing, Redshank, and Curlew). However, insufficient information is available to determine whether the current agri-environment prescriptions are optimal, or whether they require being adapted to better deliver for these species. We have no recommendations to improve the delivery of this option for farmland birds.

EK5 – Mixed stocking

This agri-environment option encourages the grazing of different livestock on agricultural holdings. The option specifies that each species should represent a minimum proportion of the overall livestock units total.

Breeding season resources

The most persuasive evidence that mixed stocking can deliver breeding season benefits for birds derives from a study by Evans *et al*. (2007). These authors manipulated livestock densities in a replicated field experiment, and demonstrated that mixed sheep and cattle grazing at low intensity enhanced the breeding abundance of Meadow Pipits after two years (Evans *et al*. 2007). In contrast, the breeding densities of this species in treatment areas stocked solely with sheep, both at high and low densities, and control plots left unstocked either declined or remained approximately constant during the same period (Evans *et al*. 2007). This finding was interpreted as low intensity, mixed stocking creating a heterogeneous sward structure, which in turn created favourable microclimates for a diverse invertebrate fauna that the Meadow Pipits could subsequently exploit (Evans *et al*. 2007). It was also suggested that cattle may attract a more varied or abundant dung insect assemblage, which might also offer profitable foraging opportunities for some farmland birds (Evans *et al*. 2007). In addition to the foraging benefits anticipated above, mixed stocking, by providing an array of different sward heights, may also cater for the nesting habitat preferences of different farmland birds, although this remains to be empirically demonstrated.

Winter season resources

There are no known benefits of mixed stocking during the winter period for farmland birds.

Conclusions and Recommendations

There is some evidence that mixed stocking may provide foraging opportunities for farmland birds, particularly during the breeding season (Evans *et al*. 2007). It is important to recognise, however, that these benefits were obtained under a regime of low intensity mixed grazing in the uplands. The mixed stocking ELS prescription in its current form does not place any restrictions on levels of grazing pressure, and consequently, it is probable that farmers will graze a maximal number of livestock under this option, resulting in the same short, uniform sward characteristic of modern intensively managed farms (Buckingham 2007). These grasslands will be impoverished both in terms of their botanical and invertebrate diversities. Therefore, currently, it is doubtful whether mixed stocking affords any appreciable benefits for farmland birds (Buckingham 2007). Inclusion of stipulations limiting the grazing intensity of grasslands would clearly offer greater potential for delivering the desired heterogeneous sward structure, but such management practices are unlikely to be tenable within a generic ELS prescription such as this.

DISCUSSION

This review has shown that there is persuasive evidence that some of the agri-environment options prescribed under ELS deliver measurable benefits for farmland birds. These benefits are in the form of nesting (e.g. ditch and hedgerow management) and foraging (e.g. grass field margins) opportunities during the breeding season, and also foraging opportunities during the winter period (e.g. over-wintered stubbles and wild bird crops). However, it should be noted that there is a considerable bias in the manner in which research on prescription efficacy has been targeted at different suites of options. In particular, the effects of the provision of field margin and arable ELS options on farmland birds have received significant research attention, but many other groups, including options for boundary features, trees and woodland, lowland grassland, and the uplands, have been less thoroughly researched. Arable regions of England harbour important populations of range-restricted species in Britain, including the Yellow Wagtail, Corn Bunting and Turtle Dove, hence the initial focus on the efficacy of these agri-environment options. Nonetheless, losses of biodiversity from lowland grassland and upland areas are often equivalent to or exceed those of arable dominated regions (Chamberlain and Fuller 2001), and the evaluation (and adjustment of) agri-environment schemes for these habitats is an imperative objective. Some recent research has begun to assess the potential merits of the lowland grassland prescriptions (e.g. Evans *et al* 2007), but ultimately, more now needs to be done to redress this imbalance.

A predominant research theme of agri-environment schemes has been devising management techniques that render existing prescriptions more optimal for agricultural biodiversity. In the case of farmland birds, experimental management practices have developed from studies of foraging habitat selection, which have demonstrated that it is not only food abundance that dictates patterns of habitat use, but food accessibility and perceived predation risk are also incorporated into behavioural decisions. These experimental techniques have therefore focussed upon manipulating the vegetation height (e.g. mowing and topping) and sward density (e.g. scarification and selective graminicides) of agri-environment habitat features to either facilitate greater access to prey resources or to better suit the particular prey avoidance strategies of different species (Butler *et al.* 2005; Whittingham *et al.* 2006; Collins *et al.* 2007). To date, the preliminary results of these experimental management techniques appear relatively promising, with birds showing positive responses in many cases. For example, in the SAFFIE study, field margin management treatment was a significant predictor of the extent of bird usage, with bird densities being particular high on the scarified and graminicide-treated boundaries (Henderson *et al.* 2007). In addition, the proportionate use of field margins in this study increased significantly over time, reflecting that managed margins become progressively more suitable for farmland birds as they matured (Henderson *et al.* 2007). Therefore, given these encouraging findings, and conditional upon similar positive benefits being demonstrated by further efficacy studies, it is the suggestion of this review that consideration should be afforded to their possible inclusion with suitable ELS prescriptions. However, it should also be noted that some of these experimental techniques require a considerable increase in the time and efforts devoted by farmers, and to act as an incentive in their uptake, point allocations will need to be revised accordingly.

For agri-environment schemes to be able to effectively counter the broad scale declines of farmland birds in Britain, they must fill critical resource gaps for target species (Siriwardena *et al.* in press). However, this review has highlighted that the provision of one key suite of ELS prescriptions, the over-wintered stubble options (EF6, EG4, EG5), may not adequately correspond with the period of greatest resource requirement. Specifically, it is the prevailing view that winter food resources for granivorous species are at their most depleted during late winter and early spring (mid Feb. to end of Mar.; Evans *et al.* 2004; Siriwardena and Anderson 2007; Siriwardena *et al.* in press), but existing prescriptions permit the ploughing of stubble fields from the 15th February onwards, thus removing a potentially very valuable food supply. It is the recommendation of this review, therefore, that consideration be given to the possibility of extending the period of obligatory stubble retention until at least the 15th March. Note, however, it is not our contention that over-wintered stubble prescriptions in their current form have been completely ineffective in combating farmland bird declines – indeed, there is good evidence to the contrary (Gillings *et al*. 2005) – but such an alteration to these prescriptions would yield maximal benefits for granivorous birds, instead of perhaps the relatively modest benefits that are currently accrued by these species.

Another common theme within this review is the finding that some agri-environment options may function as ecological traps (Weibel 1999; Bro *et al*. 2004; Cook *et al*. 2007). In retrospect, this result is perhaps not surprising, because many of these prescriptions encourage the aggregation of high densities of prey within a small proportion of the available agricultural land, within which predators may be expected to concentrate their foraging efforts. This finding has important repercussions for the nature of future investigations appraising the efficacy of agri-environment options. Firstly, instead of documenting population density and habitat use, studies of agri-environment prescriptions will need to place greater emphasis on monitoring patterns of population dynamics, including breeding success and survival, to be sure of identifying the potentially subversive effects of ecological traps (Bro *et al*. 2004). Bro *et al*. (2004) advocated the necessity of replicated field experiments monitoring patterns of demography at the farm-scale to test the impacts of agri-environment schemes. Secondly, it may also be necessary to pose additional questions in future research, including quantifying the impact of predators on farmland birds and developing mitigation measures (e.g. habitat manipulations). In addition it may be valuable to assess how prevalent an option needs to be within the broader countryside to dilute the effects of a predator trap, and to what extent the shape and composition of options in the environment modify any trap effect (Bro *et al*. 2004)? It is likely that many of the issues addressed in this paragraph could be examined by using ELS roll out as a natural experiment, integrating research into the ongoing monitoring programmes of the efficacy of agri-environment schemes (J. Vickery pers. comm.).

Finally, an important caveat to note is that this review has focussed only on how existing agri-enviroment measures might be altered to improve their delivery of food and nesting resources for farmland birds. We do not, however, consider the agronomic costs or benefits of these proposed modifications. Clearly, such considerations are important, but whether they are practically or politically feasible is beyond the scope of the current review.

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APPENDIX 3 THE IMPORTANCE OF SCALE, CONFIGURATION AND CONTEXT OF AGRI-ENVIRONMENT OPTIONS

Agri-environment schemes are the key mechanism by which resources can be delivered at a national scale for a range of declining farmland birds. How AES can be optimized in terms of biodiversity value is a key question in conservation policy in the UK (Sutherland et al. 2006) and elsewhere in Europe. A great deal of evidence exists for the quality of various farm management techniques in relation to AES options (Appendix 2a). In previous reviews, Aebischer et al (2003) and Vickery et al (2004) identified few 'resource gaps' in terms of the foraging and nesting requirements provided for birds within existing schemes, and the current report reinforces this (Appendix 1 and 5). However, important knowledge gaps remain in relation to scale, specifically: the quality of the resource created, the quantity of that resource and the way in which it is deployed i.e. targeting and distribution at the national and local scale, configuration (size and shape of options) and local and landscape effects (e.g. interactions with landscape features/types and other options).

The response of Skylarks to set-aside gives a good example of why scale issues are important. Set-aside supports high farmland biodiversity in both summer (Henderson et al. 2000a, b; Firbank et al. 2003) and winter (Buckingham et al. 1999). Despite the apparent preference of Skylarks for set-aside (Donald 2004) and the high resource base in terms of animal and plant food available, the introduction of set-aside had apparently little effect on the population. The population decline may have been slowed, but there was certainly no widespread positive effect. Given that set-aside has covered up to 11% of arable farmland in the UK (Firbank et al. 2003) and has been present over a long period (implemented in 1992) this is perhaps surprising. It is true that in the early days of set-aside, the goal was focussed on reducing agricultural production and it was only later that its value as an agri-environment scheme was recognised and the management guidelines changed accordingly. There is also a possibility that, whilst set-aside may be good as a foraging habitat for Skylarks, it may be less good as a nesting habitat as predation levels may be high (Donald 2004). However, maybe up to 80% of this set-aside is not managed optimally (either non-rotational or in the wrong location) for Skylarks (Donald 2004). In particular, set-aside is often introduced as strips rather than whole fields and these strips tend to be along field boundaries. Skylarks will typically avoid nesting in close proximity to vertical boundaries such as hedgerows (Wilson et al. 1997) presumably due to increased predation risk. Whilst set-aside is clearly an attractive habitat for Skylarks, it may not have been introduced at the right scale or in the right places, both at a field level and a landscape level, to maximise its effects on their population (Vickery et al. 2004).

The above example is important as it shows that demonstrating a significant preference for a habitat does not mean that the wide-scale introduction of that habitat will necessarily result in population-level effects. Clearly in many cases, AES have not had the desired effects (Kleijn & Sutherland 2003), even though in several cases, detailed knowledge of the AES prescription in terms of habitat preferences had been obtained through research. AES are often applied to small patches of land, creating a complex mosaic of varying habitat quality. There is a question as to whether relatively small high quality patches can collectively provide the necessary resources to reverse declines in biodiversity within an otherwise resource-poor landscape (Whittingham 2007).

These issues have important implications for the cost-effectiveness with which AES options are delivered. Knowledge is needed not only of the quality of the prescription itself (i.e. resources provided and their availability), but also of how that prescription should be introduced into the landscape. In this review we consider three questions in turn:

(i) Scale: How much of the option is needed?
(ii) Configuration: How should the option be introduced at a field scale (e.g. strip or blocks; one patch or several smaller patches of the same area; how close should they be)?
(iii) Context: Where should the option be introduced into the landscape to have a maximum effect?

We review the existing theoretical and applied literature relating to each issue, highlight any practical recommendations that can be drawn from this information and identify important research questions that need to be addressed to maximise the effectiveness of AES in general and some options in particular. For each of these three key areas we consider literature relating to prey species for birds (invertebrates and, to perhaps a lesser extent plants) and birds themselves.

SCALE: HOW MUCH OF THE OPTION IS NEEDED?

Island biogeography theory predicts that island size has a profound effect on species richness (MacArthur & Wilson 1967). This may be due to (i) area *per se*, when the probability or colonisation is related to patch area, (ii) a greater number of habitats is more likely on larger areas which could support more species (Rosenzweig 1995). This has become a key theoretical basis for conservation related issues such as reserve selection (e.g. Quinn & Harrison 1988) and fragmentation effects (e.g. Lamberson et al. 1992). With the exception of Donald and Evans (2006), island biogeography has not, to our knowledge, been applied to the situation of high quality (agricultural) habitat patches within farmland. However, there is an extensive literature on small woodlands within agricultural landscapes (e.g. Hinsley et al. 1995, Opdam et al. 1995, Bellamy et al. 1996), which has illustrated that woodland patches behave like islands for many bird species (and especially poor dispersers) in that local extinction rates are influenced by woodland size and to some extent isolation.

With respect to scale of farmland options required for invertebrates, Tscharntke & Kreuss (1999) found that richness of parasitoids decreased more rapidly with decreasing meadow size than did richness of herbivores. They also found that fallow fields supported larger populations of parasitoids attacking pollen beetles than margins. This was partly due to fallows having a larger area, but may also have been related to the fact that field margins were characterized by a high proportion of edge. The latter differed with respect to microclimate, immigrant invasions and greater impact of pesticide or fertilizer applied to the crop (see below). In contrast, Denys & Tscharntke (2002) found insect species richness was only marginally different between strips and fallow, although predator:prey ratios were higher in fallows, suggesting the number, size and spatial arrangement of habitat patches affect predator and prey insects differentially.

The abundance of small mammals was surveyed on narrow (2m) and wide (6m) margins and in farm woodlands and permanent set-aside, with particular reference to the value of these habitats for foraging Barn Owls. The highest numbers and greatest species richness of small mammals were found in 2m margins, followed by 6m margins, farm woods and set-aside (Askew et al. 2007). This illustrates that larger areas of options are not necessarily always the most beneficial (although the authors did not provide an explanation for the observed pattern).

Corncrakes on grass fields suffer high chick mortality due to mowing activities. Mowing from the inside to the outside of the field is a crucial management technique that can be applied to reduce this mortality (Green et al. 1997), but this is only really effective when field edges have some refuge habitat. Tyler et al. (1998) suggested that the optimum size of unmown margin to reduce almost all chick death would be c. 30m, but that a much smaller margin (c. 9m) would avoid up to 80% of chick deaths as most of the mortality occurred within 9m distance of the boundary.

At a larger scale, Gillings et al. (2004) considered the responses of breeding farmland bird populations sampled with 1-km^2 grids to variations in winter cropping area. They found that the area of stubble was a key positive predictor for several declining species. For skylark in particular, the model suggested that an average minimum of 10ha of stubble was needed per 1-km^2 in order to stem breeding population declines. However, the current average was estimated at only 3ha/km^2.

CONFIGURATION: HOW SHOULD THE OPTION BE INTRODUCED AT A FIELD SCALE?

Resource spacing – A general pattern observed in several studies of island biogeography is that smaller 'islands' to harbour more species in total than the equivalent area of one or a few larger islands (Quinn & Harrison 1988, Burkey 1995; Newton 1998). Possible reasons are that smaller islands have: greater collective habitat diversity; more 'trials' possible for species establishment (e.g. if extinction is not predictable and if random effects are important – i.e. there exist multi-stable equilibria); edge effects may be positive; smaller islands may have more disturbance that may reduce competition (as per the Intermediate Disturbance Hypothesis; Connel 1978). Such findings have prompted discussion over the best way to introduce islands or patches of high quality habitat into the landscape – the so-called SLOSS debate (Single Large Or Several Small; Quinn & Harrison 1988). Tscharntke et al. (2002) addressed this issue at a relatively small scale by studying butterfly communities in grassland patches of different size (300-76000 m^2) within an agricultural landscape, in order to address the question 'Given a finite total area that can be set aside for conservation,….. what spatial configuration would represent the best strategy?'. Several small fragments had more species than an equivalent area of a few large fragments. However, species groups responded differently – specialized species were much reduced in smaller fragments, suggesting that in the context of AES, there is not necessarily a solution that would benefit all species.

The degree of isolation of small woodland patches within agricultural landscapes is a contributory factor influencing the probability of occurrence of a small number of woodland specialists (Nuthatch, Marsh Tit, Long-tailed Tit; Hinsley et al. 1995, Opdam et al. 1995). However, there has been little work addressing such issues for farmland birds, a notable exception being the work of Siriwardena et al. (2006), who considered how the large-scale distribution (between 100m and 10km) of food patches in the arable landscape affected their use by birds in winter. They found significant variation in patch use in relation to separation distance, but patterns were species specific. Some species used isolated feeding sites at disproportionately higher rate than clumped sites (e.g. Blue Tit, Chaffinch), whilst other species (Reed Bunting, Yellowhammer) used the food in proportion to its availability, suggesting free movement across patches. Siriwardena et al. (2006) concluded that creating resource patches more than 1km apart would be the most cost-effective to maximise winter bird use.

Whilst Island Biogeography theory provides an interesting viewpoint from which to consider the deployment of AES patches on within farmland, it may provide only a crude approximation to patterns in mainland situations as matrix permeability is likely to be higher than on true islands (Donald & Evans 2006), i.e. patches of high quality habitat on farmland may not be considered as ecological islands. AES that 'soften' the matrix of intensive agriculture could reduce fragmentation effects in isolated patches (which is presumably one reason why some prescriptions' effects are landscape-specific), although this is likely to depend on dispersal ability, with intermediate dispersers likely to benefit most (Donald & Evans 2006).

It is also likely that the spatial scale at which resources are deployed, say within AESs, will differ between the breeding and non breeding season. In the latter birds tend to be more constrained in dispersal, acting as central place foragers with respect to hedge or field nest sites. Thus whilst patches of food can be deployed at considerable distances apart in winter (Siriwardena et al 2006) they may be required in scattered patches at a much finer scale in summer. Indeed most studies of the foraging ecology of farmland birds such as Yellowhammer and Corn Bunting suggest birds utilise food resources within ca 300m of the nest, although some species such as Linnet forage over greater distances.

Resource shape – Whilst there has been some research comparing biodiversity between margins and whole fields (Thies & Tscharntke 1999, Tscharntke & Kreuss 1999, Denys & Tscharntke 2002), very little work has been done on the shape of options *per se*. This may be important because edge:area ratios will vary according to patch shape and therefore certain configurations may be subject to greater edge effects than others.

For ground nesting farmland birds, edge effects may be key in determining predation rates. Several studies have examined experimentally predation rates at habitat edges compared to habitat interiors. Results generally, but not always, found predation rates to be higher at habitat edges (Major & Kendal 1996). However, many of these studies were carried out in forested habitats. Studies in open habitats have found vegetation structure of a patch, rather than the size, fragmentation extent or distance from edge, to be a key determinant of nest predation rate (e.g. Baines 1990, Howard et al. 2001, Willson et al. 2001). Donald (2004) found that Skylark nest survival rate adjacent to tramlines was over half that of nests built further into the crop, as these nests are likely to be more detectable to predators, especially if, as seems likely, they use these tramlines as routes of access through the crop. Set-aside established as strips or field margins tend not to be used by Skylarks, although this may be more to do with their placement in the landscape (see below) than due to predation risk.

CONTEXT: WHERE SHOULD THE OPTION BE INTRODUCED INTO THE LANDSCAPE TO HAVE A MAXIMUM EFFECT?

Local scale – The precise location of patches in relation to other habitat features at the farm scale can be important. For example, Skylarks prefer open landscapes and avoid nesting in fields in close proximity to vertical features such as tree lines and hedgerows (Wilson et al. 1997). For nesting Lapwings, spring cereals tend to be a preferred and productive nesting habitat, particularly when adjacent to grass fields (Wilson *et al*. 2001) which provide a good invertebrate food source for fledged young (Galbraith 1988). Feber et al. (1996) found that *Pieris napi* was strongly associated with northern facing experimental field edges, showing the potential importance of margin location. Siriwardena & Stevens (2004) found that use of artificial food patches by birds was influenced by local (and landscape) habitat variables.

AES options often involve the management of field margins. At the field scale the major influence on the value of a margin for birds and their food resources is proximity to a good quality hedgerow, i.e. one that is well established, relatively species-rich and well managed (Vickery et al. in prep.). This will be particularly true in summer when many species nest in or at the base of hedgerows and will preferentially forage nearby. In winter, proximity to hedgerows may be less important but they provide cover from predators (e.g. Evans 2004) and margins near hedgerows may still be favoured by foraging birds (e.g. Henderson et al. 2004). There is no information about the relative use of margins by birds with respect to field size (Vickery et al. in prep.). It is possible that margins in smaller fields have the potential to be used by more birds in summer simply because there will be a higher density of hedgerows (and hence nests) in the surrounding area. For similar reasons, it is also likely that having a margin along both sides of a hedge for say 10 m is less valuable than a margin along one side of 20 m.

Predation pressure is likely to be a key factor with respect to the local context of AES option placement. The SAFFIE experiment highlighted the importance of interactions between options. In this study the creation of skylark plots in field where field margins were also deployed resulted in nests close to those margins (<70-80m) incurring high failure rates due to predation. This was attributed to the presence of the margin enhancing predator numbers and encouraging those predators into the crop (www.SAFFIE.com).

Robinson and Sutherland (1999) showed Skylarks depleted food sources in field centres first, moving nearer to field boundaries as food decreased. Yellowhammer showed the opposite pattern. Similarly, spatial use of set-aside varies from species to species (Henderson et al. 2000a). Generalist species preferred to forage within 5m of the field boundary, but Yellowhammer also fell into this group. However, cardueline finches and Skylark favoured field centres. These preferences appear to be related to the species' respective predator avoidance strategies: Skylarks either rely on early detection and attempting to outfly predators or evade detection by crouching; Yellowhammers fly to cover (Robsinson & Sutherland 1999). For the majority of species, the latter strategy is used. Similarly, Siriwardena & Stevens (2004) suggested that differences in the use of artificial food patches by different species were in part related to their predator avoidance strategies, with skylark and linnet in particular reluctant to exploit food sources near hedgerows.

Creation of a high quality habitat that attracts large numbers of birds may act as a ‘honey pot’ for predators. Such an effect may be particularly pronounced when the surrounding habitat is of poor quality. For example, Tyler et al. (1998) suggest that Corncrake chicks could be especially vulnerable to predation if unmown margin refuges were left as islands of tall vegetation with very little cover nearby, although they suggested that further work was required to address this issue. To our knowledge such research, on Corncrakes or other species, has yet to be carried out.

Landscape scale – Several studies have demonstrated the importance of landscape context in determining the relative value of high quality habitat patches. Generally, more complex landscapes support richer and more diverse communities (Schmidt et al. 2005, Roschewitz et al. 2005), which may result in improved ‘ecosystem service’ in that parasitoids and predator communities are enhanced, thus reducing pest populations (Thies & Tscharntke 1999; Tscharntke et al. 2005). However, the effect of landscape complexity varies according to farming system (e.g. organic or conventional). For example, the species richness of spiders in winter wheat fields was related to landscape complexity (no. non-crop habitats) irrespective of farm management (organic farms had higher density of spiders). However, spider density increased with % of non-crop habitats in conventional farmland only (Schmidt et al. 2005). Similarly, Roschewitz et al. (2005) sampled weeds in wheat fields on organic and conventional farms. Weed diversity, seed rain and seed bank were higher on organic farms, but landscape complexity was more strongly related to species diversity in the conventional system. Furthermore, seed bank diversity increased with landscape complexity irrespective of farming system. The overall diversity was determined by heterogeneity within or between fields rather than landscape or farming system.

For invertebrates, dispersal ability may be a key factor underlying such relationships. For example, Hendrickx et al. (2007) carried out large-scale sampling of invertebrates over several northern European countries and found that total species richness was most strongly influenced by proximity of semi-natural habitat, but also by agricultural intensity. A key finding was that loss in arthropod species richness was due to a loss of species turnover between local communities in addition to a loss of species from those communities. In other words, in more intensive landscapes, patches were less rich and more similar to one another than in less intensive landscapes. This is probably due to a loss of more specialist but poorly dispersing arthropods. Bender & Fahrig (2005) showed through a simulation-modelling approach and a field study of chipmunks that patch size and isolation explained inter-patch movement (related to local extinction probability) well when the surrounding matrix was simple, but when the matrix was heterogenous, these variables explained far less variation.

For farmland birds, landscape context has been shown to strongly influence habitat associations. Robinson et al. (2001) found that the abundance of several farmland bird species (grey partridge *Perdix perdix*, skylark *Alauda arvensis*, tree sparrow *Passer montanus*, corn *Miliaria calandra* and reed buntings *Emberiza schoeniclus*, yellowhammer *Emberiza citrinella* and whitethroat *Sylvia communis*) increased with the amount of arable habitat present in a survey square within grassland-dominated landscapes. Furthermore, the positive association between numbers of some species and arable habitat was strongest where arable habitat was rare in the surrounding area, and weakest or even reversed when arable habitat was common. AES may therefore be particularly valuable where they enhance habitat diversity (e.g. Benton et al., 2003) and create a resource that is scarce in the landscape, such as arable habitat in grassland systems (Robinson et al., 2001).

Atkinson and Robinson (2002) suggest that AES options need to be regionally targeted to maximise their benefits on farmland bird populations, in particular by introducing some arable options into otherwise grass-dominated farming landscapes. Whittingham et al. (2007) derived regional bird-habitat models and then tested the predictive power of these models in other regions. They found that models derived from one region generally had poor predictive power when applied to other regions, suggesting that many habitat associations are region-specific and therefore that conclusions drawn on the efficacy of agri-environment measures from geographically restricted studies should not be assumed to be applicable at a national level

DISCUSSION

The extent, configuration and local and landscape context of habitats introduced to provide foraging and nesting resources for birds are undoubtedly extremely important influences on the cost effectiveness of those options. However, to date few studies have quantified the effects of such aspects of AES option deployment on birds. The extent of option required to have an effect at the population level for birds remains a key research question. Empirical studies on the extent and spatial pattern of options are rare. The former requires long term studies at a very large spatial scale and the latter requires landscape scale experiments. However, carefully designed research projects integrated with the on going monitoring of ELS could be used to address some of these issues for certain options. For example, through more detailed sampling of birds and habitats at a random sub set of sites stratified by option uptake (high, medium and low uptake of a number of key options). The approach presented in Objective 5 also provides a theoretical framework for testing predictions on the scale of uptake required. In terms of spatial distribution of resources, in general the need for a small scale mosaic (i.e. small scattered patches) is likely to be greater in summer than winter when birds are not tied to nest sites and so are, generally, more mobile. But some species, such as house sparrow and tree sparrow are also remarkably sedentary in winter.

Such seasonal differences highlight the need to provide year-round biodiversity requirements at the same location. For example, there may be no point in providing key wintering habitats for certain species if no key breeding habitat is required. This is unlikely to be a problem for highly-dispersive species, but will be crucial for poor dispersers. AES option context should therefore be viewed not only in relation to existing landscapes and habitats, but also in relation to other novel options that may be introduced to the farm landscape at the same time.

The optimal configuration (size and shape) of options also remains largely unknown. Many prescriptions for margins or in-field plots are constrained by the nature of farm machinery, with little empirical data to inform the most cost-effective procedures, e.g. boom width is a constraint on the range of possible margin widths, and there is a need to assess relative costs and benefits of different margin widths or margins versus plots. Plots may benefit certain groups as edge:perimeter ratio is minimised and therefore there will be fewer potential deleterious edge effectrs such as increased predation. On the other hand, an equivalent area of habitat configured in strips may have the function of facilitating dispersal, which is clearly a key mechanism dictating invertebrate community structure across farmland habitat patches (Hendrickx et al. 2007). This could be especially valuable if such strips acted as corridors linking larger areas of high quality habitat. To our knowledge only one on going study has been specifically designed to address the latter issue, whereby strips and blocks of uncropped land under different management regimes are being compared in terms of biodiversity (plants, insects, birds and mammals) in a large-scale experimental set-up (Holland et al. 2007). The results of this study should prove extremely valuable in assessing the effect of configuration of AES options on farmland biodiversity.

The way in which the local and landscape context of options influences delivery is know to be extremely important. At a local scale there may be positive interactions between options (synergistic effects); for example, enhanced invertebrate populations in margins adjacent to good quality hedges as opposed to poor quality hedges or no hedges. There may also be negative interactions such as increased predation in skylark plots near enhanced field margins compared to those in field centres or in fields with no margins. At a landscape scale, the creation of options that enhance habitat diversity affords marked benefits to birds e.g. grass pockets in arable land and arable pockets in grass land. Similarly, sympathetic management of habitat patches or options in highly intensive agricultural landscapes may provide a greater overall increase in species diversity and abundance than in more extensive landscapes. However, management in the latter may enhance numbers of species of greater conservation concern.

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APPENDIX 4 EFFECTS OF VARIATION IN THE AVAILABILITY OF SET-ASIDE ON POPULATIONS OF FARMLAND BIRDS

INTRODUCTION

Removing land (i.e. set-aside land) from agricultural production was an initiative introduced in 1988 by the European Commission, as part of the Common Agricultural Policy (CAP), to reduce agricultural surpluses (Firbank *et al*. 2003). Initially, this scheme operated voluntarily, but following CAP reforms in 1992, eligibility for agricultural subsidies required that a proportion of arable land should be set-aside each year (Firbank *et al*. 2003). Since 1994, the amount of set-aside in the English agricultural landscape has fluctuated in line with both annual changes in the predetermined rates required of farmers wishing to receive Arable Area Payments and in the amount of voluntary fallow land left by farmers as part of their normal agricultural operations. Over this period the set-aside area has fluctuated between c. 250,000 and c. 575,000 ha, but on average, has constituted approximately 10% (c. 500,000 ha) of all arable land.

It is becoming increasingly clear that the introduction of set-aside in Britain, and more widely in Europe, has had beneficial repercussions for agricultural biodiversity. Studies of diverse taxa have suggested that species richness and population densities are often higher on set-aside than other types of land (reviewed in Buskirk and Willi 2004). The response of birds, in particular, to the provision of set-aside land has been well studied and recently reviewed in (Roberts & Pullin 2007). For example, Henderson *et al*. (2000) demonstrated that the relative abundance of birds during summer was higher on (rotational) set-aside than any other crop type for five of six functional groups of farmland birds (gamebirds, pigeons, Skylarks, thrushes and granivores). Furthermore, Buckingham *et al*. (1999) documented that five declining bird species (Grey Partridge, Linnet, Skylark, Yellowhammer and Cirl Bunting) preferentially selected fallow land (mainly set-aside) relative to other crop types during winter in Devon and East Anglia. The attractiveness of set-aside to farmland birds has generally been attributed to the enhanced foraging opportunities afforded by this habitat type (Henderson *et al*. 2000). It potentially provides a rich source of insects and weed seeds providing food in both summer and winter, the accessibility of which is enhanced by the patchy nature of the sward. It also provides nest sites for ground nesters such as Skylarks (Henderson *et al*. 2000).

Given the putative benefits offered by set-aside to farmland birds and that it has been a significant component of the agricultural landscape for over a decade, an obvious prediction is that it will have positively affected the population trends of some species. However, several authors have commented that the provision of set-aside has, in fact, had few measurable effects on the population trends of species exhibiting a close association with it (Fuller 2000; Henderson *et al*. 2000; Firbank *et al*. 2003). Nevertheless, it should be noted that these assessments have been based on a few species, using visual appraisals of the concordance between set-aside introduction and changes in bird populations. Here, we present an analysis of the effects of the provision of set-aside land on the population trends of the nineteen Farmland Bird Index (FBI) species. Our prediction is that variation in the availability of set-aside will be paralleled by fluctuations in the trends of some species.

METHODS

Data on bird population trends were derived from the BTO/JNCC/RSPB Breeding Bird Survey (BBS), a volunteer-based census that provides an index of annual changes in bird populations in Britain. A detailed summary of the census methodology and statistical techniques used by the BBS to generate these trends is beyond the scope of the current report, but can be found in other publications (e.g., Buckland *et al*. 2005). We obtained national (i.e., all England) trend data for each of the 19 species included in the FBI (see table A4.1), and a composite trend describing the mean changes of all FBI species during the period 1994-2005. Information on temporal changes in the availability of set-aside for this period was obtained from the Defra farming statistics online database[1].

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[1] http://www.defra.gov.uk/esg/work_htm/publications/cs/farmstats_web/default.htm

To evaluate whether changes in the availability of set-aside were associated with fluctuations in the population trends of individual species and the composite trend, we used Spearman's partial rank correlation analyses implemented in SAS v. 9.1 (SAS Institute, 200?). This method of analysis makes no distributional assumptions about the data, but allows possibly confounding factors to be accounted for. As trend indices in consecutive years are autocorrelated, between-year changes (index yr *n*/index yr (*n*-1)) in trend values were correlated with absolute values of set-aside (set-aside is not characterised by autocorrelation). We tested both for effects of the availability of set-aside in year *n* and in year (*n*-1) on bird population trends. Moreover, during exploratory rounds of data analysis, we noted that considerable declines in the composite trend of the FBI species coincided approximately with consecutive cold winters in 1996/97 and 1997/98. Therefore, mean winter temperature was incorporated in analyses as a partial variate to control for any fluctuation in population trends that was attributable to variation in winter climatic conditions. Finally, note that data from 2001 was disregarded from analyses, because the outbreak of Foot and Mouth disease amongst cattle in that year, and the subsequent restrictions regarding access to the countryside, meant that measures of bird population trends had to be interpolated from data in previous and subsequent years.

RESULTS

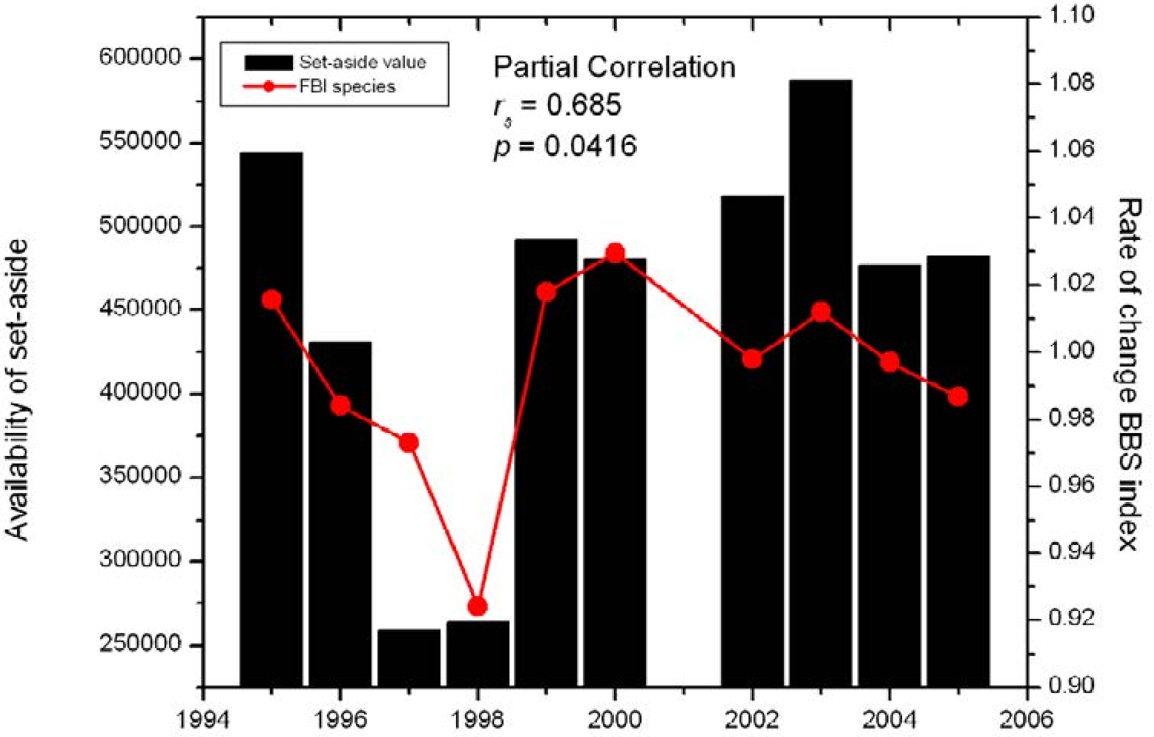

Figure A4.1. Temporal fluctuations in the rate of change of the composite BBS trend for all FBI species and in the availability of set-aside land. (2001 was removed from the analysis see text). Note that although the required rate between 1999 and 2005 remained constant at 10% there were notable annual fluctuations in the actual area due to additional voluntary set-aside/fallow land. No data are presented from 1994 as the rate of change in the BBS index relates to the change between 1994 and 1995.

The BBS population trend for all FBI species was significantly positively correlated with the availability of set-aside in year *n* (fig. A4.1). Furthermore, the individual trends for two species, Lapwing and Linnet, were also significantly positively related with set-aside in year *n* (Table A4.1). Of the 17 FBI species not characterised by a significant relationship (Table A4.1), 11 were positively associated, and six negatively associated with set-aside in year *n*; these disparate counts were not statistically significant (binomial test, $p = 0.3323$). In contrast, the individual-species and composite-species trends did not vary significantly with the availability of set-aside in the preceding year, although Grey Partridge did show a trend towards being positively influenced (Table A4.1).

	Set-aside in year *n*		**Set-aside in year (*n*-1)**	
Species	**Partial Correlation**	***p*-value**	**Partial Correlation**	***p*-value**
Corn Bunting	0.456	0.2174	0.095	0.8072
Goldfinch	0.56	0.1168	0.3	0.4332
Greenfinch	0.028	0.944	-0.114	0.7702
Jackdaw	0.505	0.1654	-0.237	0.5385
Kestrel	0.116	0.7661	-0.425	0.2544
Lapwing	***0.834***	***0.0052***	0.144	0.7121
Linnet	***0.791***	***0.0112***	0.439	0.237
Grey Partridge	-0.086	0.8247	*0.621*	*0.0743*
Reed Bunting	0.344	0.3645	-0.349	0.3579
Rook	-0.269	0.4837	-0.147	0.7063
Skylark	0.39	0.2998	0.364	0.3353
Stock Dove	-0.426	0.2531	0.381	0.3112
Starling	0.183	0.6369	-0.033	0.9329
Turtle Dove	-0.003	0.9935	-0.1	0.797
Tree Sparrow	0.218	0.5723	0.15	0.6993
Whitethroat	-0.137	0.7252	0.49	0.181
Wood Pigeon	-0.492	0.1787	-0.315	0.409
Yellowhammer	0.317	0.4056	-0.356	0.3467
Yellow Wagtail	0.379	0.314	0.575	0.1051
Mean Trend	***0.685***	***0.0416***	0.282	0.4622

Table A4.1. Partial correlation coefficients and *p*-values of correlations between FBI species and the availability of set-aside in year *n* and year (*n*-1).

DISCUSSION

The most striking finding of this analysis is that the composite trend for all FBI species varied according to the availability of set-aside, with more positive between-year population changes associated with an increased provision of set-aside. Examining fig. A4.1, perhaps the most persuasive demonstration of this correlation is the precipitous decline in the BBS trend following a marked reduction in the amount of set-aside in 1997 and 1998. This reduction occurred because the predetermined set-aside rates fell from 15% of arable land in 1996 to only 5% in 1997; Henderson *et al* (2000) suggested that this represented 'one of the single largest changes in farming practice over two years.' That farmland birds fluctuated in response to this event affords confidence that it is changes in the availability of set-aside, and not a third intercorrelated variable, to which birds are responding.

In addition, the species-specific trends of Lapwing and Linnet were also positively associated with the availability of set-aside. Set-aside could benefit bird species both in winter and in the breeding season. Set-aside is known to be a favoured habitat for Linnet during winter (Buckingham *et al.* 1999), presumably because it offers an abundance of weed seeds; consequently, changes in its availability are likely to impact on over winter survival of this species. In contrast, although Lapwing preferentially select set-aside during the breeding season (Wilson *et al*. 2001), there is relatively little evidence implying that it is an important habitat in winter. Therefore, the route by which fluctuations in the amount of set-aside might influence the survival of Lapwing may well be improved productivity. Finally, it is noteworthy that although most are non-significant, the correlation coefficients for 8 granivorous passerines (corn bunting, goldfinch, greenfinch, linnet, reed bunting, skylark, tree sparrow and yellowhammer) in the above analyses are positive, which would be anticipated from existing knowledge of the use of set-aside by these species.

The results presented above are clearly suggestive of the fact that changes in the availability of set-aside can influence the populations of some bird species, but in reality, we would advise prudence in both their interpretation and extrapolation. A principle sticking point is that the intriguing relationship suggested by the correlation between the composite FBI trend and set-aside is not really borne out in the analysis of species-specific trends. Only two farmland birds, from a total of nineteen species, exhibited a significant correlation with the amount of set-aside, a number that could easily have arisen as a result of Type I error. One possible explanation for the absence of a significant correlation in some species that would be anticipated to benefit from the provision of set-aside (e.g. Corn Bunting, Tree Sparrow) is that, due to their rarity, trends are based on relatively few BBS squares, and thus there is a significant degree of imprecision associated with the population estimates. Within such species, it may be relatively difficult to detect changes in population size associated with fluctuations in the availability of set-aside. To remedy this, it may be possible to eliminate data deficient species from the analyses, although, by definition, this would see the removal of rare species from the analysis. Another more sophisticated option may be to weight correlations by associated measures of precision to control for differences in estimate accuracy. This issue clearly requires further exploration. Other approaches that we would propose to perform in future analyses to improve our understanding of the relationship between set-aside and bird population trends include:

i) to extend the time series back to 1988 using data from the Common Birds Census (CBC);
ii) to use the area of spring barley as a surrogate for the area of over-winter stubble created as part of the normal farming rotation and to see whether adding this to set aside area improves the correlation,
iii) as (ii) but extend the time-series back to 1970
iv) to explore how grouping the birds according the different taxonomic, feeding etc. guilds affects the direction and significance of correlations.

Due to proposed reforms of the CAP by the European Union, it is very likely that set-aside will disappear from the farming landscape in 2009. The results of this analysis suggest that without its substitution with an agricultural habitat with equivalent biodiversity benefits, this removal could precipitate a further reduction in the populations of European farmland birds. Nevertheless, it cannot be stated with too much emphasis that the results presented here should be considered as preliminary, and that further rigorous analysis should be undertaken before weight is ascribed to the potential consequences of changes in the availability of set-aside on farmland bird populations.

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APPENDIX 5 DEMOGRAPHIC RATES REQUIRED TO PRODUCE POPULATION GROWTH

AIMS

(i) To determine the magnitude of change in key demographic parameters required to result in population increase of 1% over a period of 1 year for farmland birds.

(ii) To determine how the magnitude of change in key demographic parameters required to result in 1% growth varies if only a proportion of the population is subject to a change in those parameters.

METHODS

The methodology used in this section derives key information from Siriwardena & Vickery (2002). For brevity, we refer to this work as 'S&V' followed by the relevant table in that reference if used as a data source for the current analyses. The analyses were based on the calculation of inter-annual change based on demographic parameters, expressed by the following equation in S&V:

$$N_{t+1} = (N_t \times S_{AD}) + (N_t \times S_{FY} \times FPA \times S_{PF} \times NA \times 0.5) \qquad \text{eqn. 1}$$

where N_t and N_{t+1} is abundance in years t and t+1, S_{AD} is adult survival, S_{FY} is first-year survival, S_{PF} is post-fledging survival, FPA is fledglings produced per breeding attempt and NA is the number of breeding attempts per year. (Note that multiplication by 0.5 on the right hand side of the equation is to account for FPA and NA being measured per pair rather than per individual). For some species, only juvenile survival S_{JV}, rather than S_{FY} and S_{PF}, was available from the literature. In these cases, S_{JV} replaced S_{FY} and S_{PF} in eqn. 1.

For certain analyses, combined annual survival of adults and juveniles (S_{ALL}), taken as the average S_{AD} and S_{FY}, was calculated. The basic demographic model of eqn. 1 therefore simplifies to:

$$N_{t+1} = S_{ALL} \times (N_t + (N_t \times FPA \times S_{PF} \times NA \times 0.5)) \qquad \text{eqn. 2}$$

or, for species where only S_{JV} was available:

$$N_{t+1} = S_{ALL} \times (N_t + (N_t \times FPA \times NA \times 0.5)) \qquad \text{eqn. 3}$$

Demographic parameter estimates were derived for 18 Farmland Bird Indicator (FBI) species using data from S&V Table A5.3 (Barn Owl was originally included, but has since been dropped from the FBI). Parameter estimates in this table were derived from the literature and were subsequently adjusted in order to provide the best fit to the population trends. Estimates for a further FBI species, Grey Partridge, were taken from Aebischer (2002). S&V used CBC data only to derive population growth rate (PGR) for each species between 1990 and 2000. These estimates were updated using combined BBS and CBC data from 1990-2005 for England only. Recent research has shown that, for most species, the two survey methods can be combined without causing significant bias in the measurement of overall population trend (Freeman et al. 2007). PGR was derived for each species using the log-linear Poisson regression approach of S&V. Model fit was assessed by comparing the predicted PGR (using the parameter estimates of S&V Table A5.3 in eqn. 1) and the observed PGR (from log-linear Poisson regression of data from 1990-2005). Where observed and expected PGR differed by more than 1%, parameter adjustment was carried out, following the methods of S&V. In most cases only very small adjustments to parameter estimates were necessary to produce a predicted PGR that was within 1% of the observed PGR. The exception was Rook which is not covered in BBS and so the original parameter estimates of S&V are retained for this species. The updated demographic parameters and PGR for each species are shown in Table A5.1.

For each species, S&V Table A5.4 identifies the key demographic parameter (and in some cases parameters) that is likely to be the main driver of population change. We used the parameters listed in S&V as the key parameters, but we also added an additional key parameter, FPA, for Reed Bunting. In this species, survival appears to have driven the decline, but low productivity rather than survival is likely to be inhibiting population recovery in this species (Peach et al. 1999).

We determined the demographic rate required to increase the population by 1% over one year, from a starting value of $N_t = 1$, by rearranging eqn. 1. (A similar exercise was carried out in S&V Table A5.5, except that the demographic rate required to reach population stability was determined). Where the key parameter was identified as 'Survival' in S&V Table A5.4, and was therefore not linked explicitly to either adult or first year survival, three different survival parameters were calculated: adult survival S_{AD}, first year survival S_{FY} (or juvenile survival S_{JV} if appropriate) and combined adult and first year survival S_{ALL} (from eqn. 2 for species where S_{PF} and S_{FY} were estimated separately and from eqn. 3 where only S_{JV} was available). However, for the main report, we present results for only S_{FY} or S_{JV}, as much of the evidence suggests that juvenile rather than adult survival is likely to be the main driver of population change in several species. Key results for S_{AD} and S_{ALL} are given in Appendix I.

ELS option uptake

A matrix of farmland bird species versus individual ELS options was constructed. Each option was classified as having effects on population parameters for each through three resource types: nesting habitat, summer foraging, winter foraging. These effects were defined as 'probable' (defined according to published evidence), 'potential' (where the authors thought there was likely to be an effect according to general ecological knowledge, but where no published evidence existed for the effect, either positive or negative) and no effect. Then, for each bird species, farm holdings on the national ELS database were classified according to the number of habitat resource types (nesting, summer foraging, winter foraging) for which at least one relevant option was present. This was done for two sets of options: (i) those with a high probability of option providing resource, plus those with a lower probability (i.e. 'probable' and 'potential' effects combined, referred to as the 'potential' scenario); (ii) those with a high probability only (the 'probable' scenario), for the species concerned.

ELS areas were summed over all England, therefore for each species it was possible to estimate the area that would positively effect nesting habitat, summer food and winter food under ELS. Note that only the area of farm holdings with a particular option, rather than the area of the option per se, was available for this calculation. The analyses therefore make the assumption that option effects are at the farm level. There was a total of 25,697 holdings, summing to 3,505,823.25 ha (as of 02/11/2006) taking part in ELS. The areas of each option or combination of options providing nesting habitat, summer food and winter food were expressed as proportions of area of holdings in the entire June Survey data, i.e. the area of agricultural holdings registered with Defra. There were 195,908 holdings in total, covering 9,397,857 ha (data from June Census 2005; 2006 data were not available at the time of data extraction). At the time of writing, the current overall proportion of the June Survey area with an ELS agreement was: 3505823/9397857*100 = 37.30%. In order to calculate the potential habitat availability if uptake were to increase to 70% of the June Survey area, estimates were scaled up by 70/37.3 = 1.877.

Model scenarios

The above approaches were used under several different scenarios- 8 in total. For 'probable' and 'potential' scenarios respectively, models were constructed that considered: (i) current ELS uptake, varying only the key parameter; (ii) increased national ELS uptake of 70%, varying only the key parameter; (iii) current ELS uptake, varying all parameters; and, (iv) 70% ELS uptake, varying all parameters. A range of scenarios that consider relatively small through to relatively large effects of ELS on demographic parameters and therefore population change are therefore considered.

RESULTS

Demographic rate required for population increase

The key demographic rates required to achieve 1% population growth for each species are given in Table A5.2. For a number of species, the increase required in the key parameter to produce population growth was small. For example, less than 10% increase is required for Kestrel, Lapwing, Skylark, Yellow Wagtail, Linnet, Yellowhammer and Reed Bunting. For others, the change would have to be larger, e.g. Grey Partridge, Turtle Dove and Corn Bunting each had at least one key parameter requiring an increase of > 10%.

Required rates for proportions of the population

The introduction of measures to improve demographic rates in farmland birds and therefore to increase populations is likely only to be applied to a certain proportion of a population, whereas in Table A5.2, it is assumed that 100% of the population will change their key demographic rate (or, more realistically, that the population average will increase to the required rate). The next stage was therefore to see what the key demographic rate to achieve population growth would be for each declining species if only a proportion of the population increased that demographic rate (the remainder of the population is assumed to have the baseline demographic rates as presented in A5.2).

Variation in the key demographic rate required to achieve population growth for each of the species that has a PGR of less than 1.01 (i.e. excluding those marked 'none†' in Table A5.2) was considered in relation to the proportion of the population where that rate was able to increase. For example, in Fig. A5.1, FPA for Kestrel would have to be 3.70 for 50% of the population if the entire population were to achieve 1% growth. If only 10% of the population were to increase FPA, then this parameter would have to reach 4.45 for the entire population to grow.

Table A5.3 summarises the magnitude of the key parameter(s) required to achieve population growth when 90%, 50% and 10% of the population is affected by the increased demographic rate. Naturally, the magnitude of the required key parameter estimate increases as the proportion of the population affected decreases. In cases where the key parameter is survival rate, the model requires that the rate increases above 1 which is of course impossible so in these cases, even 100% survival rates would not increase the total population size.

Required rates in context

It is difficult to interpret Table A5.3 without some estimates of the increases that are realistically possible. For example, is it a realistic target to increase the S_{FY} of Corn Buntings by 11% (leading to population growth, if 50% of the population were affected), or even 95% (leading to population growth, if only 10% of the population were affected)? In order to put the figures in Table A5.3 into context, a literature search was carried out into the key parameters in each species in order to identify maximum values for each parameter. Where possible, these estimates were derived from farmland populations in the UK and preferably from stable or increasing populations, although there were instances where estimates were made from non-farmland habitat (e.g. Skylark), or using rates from closely related species (Corn Bunting first-year survival) due to a lack of information in the literature. For Yellowhammer, maximum survival rates were only available from Siriwardena et al. (1998) and were not substantially different from the current estimates in Table A5.1. For this species, the maximum rate was taken as the highest survival rate in Siriwardena et al. (1998) plus 1 standard error for S_{FY} (and S_{AD} – see Appendix I). In all cases, mean values were used from a given study, rather than selecting maximum values of individual birds. These rates are shown in Table A5.4, along with data sources and caveats on interpretation.

The question was then asked: what proportion of the population should reach the maximum key parameter in order to produce population growth? The calculation of this figure is shown in Fig.

A5.2, again taking Kestrel as an example. The lower dashed line shows the baseline rate of the key demographic parameter used in the current model (Table A5.2), the curve shows the demographic parameter required to achieve population growth and the upper dotted line shows the maximum key demographic parameter from Table A5.4. If we assume that increasing the key demographic parameter above this maximum is not possible, then where this dotted line crosses the curve gives a measure of the minimum proportion of the population that would need to increase its key demographic parameter in order to affect overall population growth. In the example (Fig. A5.2), 25% of the population (as indicated by the shaded arrow) achieving the maximum key parameter would result in population increase. If less than 25% of the population were affected, population growth would not occur as it is assumed that the key parameter cannot be increased over its maximum value.

The minimum proportion of the population that could result in population growth if the maximum key parameter was reached is shown for each declining species (and each separate key parameter if appropriate) in Table A5.5.

The above analyses have considered varying only one parameter at a time. However, it seems likely that management options that are introduced that may have a primary effect on the key parameter are also likely to affect other demographic parameters. One of the most obvious cases is likely to be adult and first year survival as these two variables are usually affected by the same factors (e.g. winter stubble availability for granivorous passerines), although possibly not to the same extent. It is also possible that other demographic parameters are inter-dependent. For example, an increase in survival seems likely to increase average bird condition which itself may lead to greater productivity. To incorporate this possibility, models were re-constructed assuming that all parameters increase as the key parameter increases, but by a relatively low amount taken as 1.0%. Key parameters remain as before. NA was not increased for those species that are known to only make 1 attempt per year (e.g. Grey Partridge). The results are also shown in Table A5.5. The adjustment naturally resulted in a lower proportion of the population needed to increase the key parameter to cause population increase in every species. In many cases, the increase in other parameters was sufficient to increase the population by 1% without any increase in the key parameter. Under these models, the hypothetical requirement of the proportion of the population required to be affected is 0 (given as ‘<0.01’ in A5.5), because the increase in other (non-key) parameters is constant for a given level of key parameter increase (although in reality we would expect the non-key-parameters to increase in-line with the key parameters and in response to a change in the environment). The key message from these results is, however, that a small overall improvement in a range of demographic parameters may be sufficient to produce a population increase for these species, namely Kestrel, Lapwing, Tree Sparrow and Reed Bunting.

ELS option area and key demographic rates

If it is assumed that ELS options are placed in the lowland farmland environment at random with respect to bird distribution, then the proportion of the population required to increase its key parameter to achieve population growth (i.e. the x-axis in Figs A5.1 & A5.2) can be considered equal to the area of farmland required (because the population will be randomly distributed across the landscape and its distribution should therefore be in direct proportion to the area of different option types). This enables an estimation of whether the current uptake of ELS options relevant to individual species’ key parameters is likely to be adequate to encourage population growth. For example, in Fig. A5.2 the key parameter would have to increase to the maximum value on a minimum of 25% of the area in order to produce a 1% annual growth rate.

For each ELS option, the likely effect on summer food, winter food and nest sites was determined for each species using a three-level classification: probable effect, potential effect and no effect. The total area of farmland that had options affecting each species key parameter was also determined. The estimate of the proportion of farmland containing options affecting key parameters can be used in conjunction with the model in Fig. A5.2 to estimate the magnitude of the key parameter that would be required to result in population growth given the area affected. This is illustrated with a further example in Fig. A5.3. The number of nesting attempts (NA) has been identified as the key parameter driving Skylark population declines in several studies (e.g. Wilson et al. 1997, Chamberlain et al. 2000, Donald 2004). Currently, an estimated 10% of farmland will include ELS options that will have a probable effect on NA and 34% that will have a potential effect on NA for breeding Skylarks. According to Fig. A5.3, the former scenario, illustrated by the red vertical arrow, would require ELS options to increase NA to 3.4 (a 70% increase on the current value) and the latter scenario, illustrated by the orange vertical arrow, would require ELS options to increase NA to 2.4 (a 20% increase). The maximum value, shown as the grey arrow in Fig. A5.3, allows the above figures to be put into context. Clearly, an increase to 3.4 attempts is unrealistic as it considerably exceeds the maximum value. An increase to 2.4 attempts seems more reasonable, but the estimated area from which this figure is derived is based on relatively little evidence.

The approach taken in Fig. A5.3 was repeated for all species that have PGR of less than 1%. A summary is given in Table A5.6. Whether the required parameter estimate was achievable or not was defined in relation to the maximum value and the current rate of that parameter. If the required parameter was greater than the maximum rate, the target was considered unachievable. If the required parameter was less than the maximum rate, but still a relatively large increase compared to the current rate (taken as greater than 25% increase), the achievability of the target was defined as ‘possible’. Otherwise, the target was defined as achievable. When considering ‘probable’ effects of ELS on the key parameter, there were only three species where the required parameter was considered an achievable target: Kestrel, Tree Sparrow and Reed Bunting. Considering ‘potential’ effects usually increased the proportion of farm area affected substantially and therefore there were many more species where the target was considered achievable. Exceptions were Turtle Dove and Corn Bunting (the latter for S_{FY} only) where the required rate exceeded the maximum rate, and Grey Partridge, Skylark, Yellow Wagtail, Starling and Corn Bunting where a large (>25%) increase in the key parameter would be required to result in population growth.

Table A5.7 presents the above classifications in relation to the proportion of area required to reach population growth when the maximum parameter is attained. The latter values are from Table A5.5. Table A5.7a is a summary of the results in Table A5.6. Table 5.7b shows the results of the modelling exercise if ELS uptake nationally were 70%, the current predicted uptake. The proportion of area covered by the relevant options has been adjusted accordingly. In most cases, this high uptake results in many more achievable required rates, especially under the ‘potential’ scenario. However, Lapwing, Turtle Dove, Yellow Wagtail, Linnet, Yellowhammer, Reed Bunting (FPA only) and Corn Bunting (S_{FY} only) did not reach achievable targets under the ‘probable’ scenario.

The models in Table A5.7 were re-run considering a small increase in non-key parameters as well as potentially larger increases in the key parameter (as was done in Table A5.5). Results are given in Table A5.8. Despite the resulting lower proportion of area required to achieve population growth compared to Table A5.7, there were still some species where the estimated area of ELS would not be enough to increase the population: Lapwing, Turtle Dove, Yellow Wagtail, Skylark, Linnet, Yellowhammer and Corn Bunting (Table A5.8a). When assuming a national 70% uptake of ELS, Lapwing, Turtle Dove, Yellow Wagtail, Linnet and Corn Bunting required parameters were still classed as unachievable under the probable scenario (Table A5.8b). All were classified as achievable under the ‘potential’ scenario.

Note that although Lapwing is currently increasing (at a very slow rate) and that only a very small percentage of farm area is required to affect its key parameter (FPA), there were no options under ELS that would have ‘probable’ effects on FPA in this species, hence the target required rate is classified as unachievable.

Specific effects of ELS options on key parameters

For most species, the precise effects of agri-environment schemes on key parameters have not been estimated. For the most part, the evidence for the benefits of agri-environment scheme options to birds comes from monitoring studies (e.g. higher densities and/or preferential selection of particular options) or from indirect evidence (e.g. greater abundance of availability of bird food sources on options). Therefore, use of the maximum estimates (Table A5.4) as surrogates for possible beneficial effects of agri-environment options on key parameters provides our best available scenario. There are two species, however, where we are able to directly assess the likely impact of particular ELS options on demographic parameters, Grey Partridge and Skylark. However, it should be noted that in neither case were benefits acting on the key parameter. For each of these species we determine the proportion of farmland under the relevant ELS option that would be required to result in a population increase of 1% over a one year period.

Grey Partridge- Grey Partridge chick survival rate and brood size have been shown to be higher on conservation headlands, an insect-rich brood rearing habitat. Sotherton et al. (1993) found chick survival rates to be 0.23 on conventionally farmed areas and 0.39 in areas with conservation headlands. Other studies have produced similar estimates (Aebischer 2002). For the purpose of this exercise, we use a figure of 0.38 as a typical effect size on S_{PF} of conservation headlands (following Aebischer 2002).

Models were derived based on parameter estimates in Table A5.1. The relative population size after 1 year was determined for different proportions of the population that experienced an enhanced S_{PF} . This is shown graphically in Fig. A5.4. The relative population size reaches above 1 when approximately 37% of the population is subject to increased S_{PF}. Therefore, we estimate that 37% of the population subject to effects of conservation headlands increasing S_{PF} will result in population growth. However, the cover of options that enhance summer food for partridges is only 24% of farmland. Therefore, there is a clear shortfall in the amount of relevant options required to reverse population trends.

Skylark- Skylarks have been shown to have a slightly higher clutch size and greater nest survival on Skylark plots, resulting in a total of 1.75 fledglings per pair for plots compared to only 1.25 for conventional wheat over the whole breeding season. For the later breeding season, the difference was even greater at c. 2.5 at 1.0 respectively (Morris et al. 2007). For the purposes of the model, we assume the effects of the Skylark plot option increase FPA to 1.75 and that other parameters remain as in Table A5.1. The modelling procedure used for Grey Partridge (Fig. A5.4) was repeated for Skylark. Fig. A5.5 suggests that 20% of the population subject to enhanced FPA due to Skylark plots would result in population growth. However, Skylark plots cover only an estimated 1% of farmland, therefore this option alone would not be sufficient to reverse population declines in Skylark.

Although Morris et al. (2007) did not explicitly measure the number of attempts, there was a strong suggestion that there were more attempts in Skylarks plots compared to winter cereals as the former treatment showed continued high densities into the later part of the breeding season, whereas conventional winter cereals showed a marked decline, averaging only 49% of those in Skylark plots. A further model that assumed the effects of the Skylark plot option increased simultaneously FPA to 1.75 and NA to 3.0 (i.e. 50% increase) predicted that only 5% of the population would need to be nesting on Skylark plots to increase the population over the six year period. This is a substantial improvement on the previous model, but still exceeds the current area of Skylark plots.

BAP Targets

The modelling approach adopted so far has considered key parameters required and the area of farmland likely to deliver for certain key parameters in order to produce a 1% population growth in a subsequent year. However, smaller increases in demographic parameters may result in population growth over a longer time span (due to year-on-year population growth in that proportion of the population where the demographic parameter is increased). The analyses developed above were adapted to estimate the proportion of the population (and hence farm area) that would need to increase the key parameter in order to meet longer-term BAP targets for the seven relevant BAP species whose target is measured as a population trend (Grey Partridge, for example, is not included as the BAP target is for geographical range and actual population size). The baseline year for these models was set at 2003, in line with BAP targets. As before, these proportions were also calculated when other (non-key) parameters were increased by 1%. Results are shown in Table A5.9. In most cases the proportion required was >20% when only the key parameter was affected and >10% when other parameters were also affected. Exceptions were Tree Sparrow, Corn Bunting (S_{FY} only) and Yellowhammer.

With reference to the current proportion of farmland area under the relevant options and the target proportion if 70% national uptake of ELS is achieved, the results of Table A5.9 were subject to classification in terms of whether the BAP target was likely to be achievable under different scenarios (as per Tables A5.7 & A5.8). The results are shown in Table A5.10. As previously, whether an option is defined as having ‘probable’ or ‘potential’ effects on the key parameter and whether the key parameter is considered in isolation or if increases in other parameters are also assumed, have a major influence on whether targets are considered achievable. However, there are some patterns to emerge. Turtle Dove appeared least likely to reach the BAP target overall, the target being classed as achievable only in the least conservative scenario. The target for Linnet was considered achievable only under the ‘potential’ scenarios. Skylark, Corn Bunting (for S_{FY}) and Yellowhammer also had several targets considered non-achievable. Conversely, results for Tree Sparrow, Corn Bunting (for NA) and Reed Bunting (for S_{FY}) suggested that BAP targets were achievable under any scenario.

DISCUSSION

The results have considered a range of different scenarios under which ELS options may affect key demographic parameters. A simple method of ranking species in terms of the likelihood of ELS achieving 1% growth in each species is given in Fig. A5.6. Here, each scenario in Tables 5.7 and A5.8 is given a score according to whether population growth is deemed achievable given the parameter estimate required and the area of relevant ELS options: 0 for not achievable, 1 for possibly achievable and 2 for achievable. Fig. A5.6 shows that Corn Bunting (S_{FY}), Turtle Dove, Yellow Wagtail, Linnet and Lapwing were likely to be relatively poorly served by ELS options according to Fig. A5.6, each achieving <=50% of the possible maximum score.

Fig. A5.6 suggests that certain species are likely to be well served by ELS. Note however that there are two factors that dictate the outcome of the analyses and whether targets are achievable: (i) the degree of population decline; (ii) the area of relevant option. Therefore, a species can score highly in Fig. A5.6 due to the demographic parameters in the model, rather than the area of ELS options. For example, Kestrel and Tree Sparrow in particular had achievable targets across the different scenarios. The former due to a relatively high cover of suitable options (especially those that promote small mammal populations), but the latter was more to do with the fact that the species is currently increasing (albeit slowly), so only a very small area of relevant options are required to affect a 1% growth rate.

Turtle Dove nesting attempts have declined substantially and this appears to be the major factor underlying the population decline (Browne & Aebischer 2004). However, it appears that the number of attempts is primarily limited by adult condition rather than nest sites. Turtle Doves feed mostly on weed seeds and as such required weed-rich habitats in the breeding season. Options that are known to enhance Turtle Dove preferred foraging habitats such as conservation headlands and uncropped cultivated margins (EF09-EF11) have a very low uptake, although there are a number of options with reasonable uptake that may deliver e.g. pollen and nectar mix (EF04, EF05) and low input pasture (EK02, EK03), although there is no published evidence that this is the case.

Along with Turtle Dove, Linnet is the only species that feed their young on seeds rather than invertebrates. The key parameter identified was fledglings per attempt suggesting the availability of seed rich habitats in the breeding season may be a limiting factor. For this species there are a lot of options that will potentially deliver food for Linnet in the summer, but there is little scientific evidence for the extent of this delivery, so there is a marked difference between the extent of options categorised as 'potential' and 'probable' delivery.

Three species that require in-field nesting habitat are not likely to be well served by ELS, especially when considering 'probable' option effects. This is a result of the fact that options providing nest sites are either relatively few in number and/or uptake is poor. Thus, for Skylark and Yellow Wagtail, nest sites may be provided by stubble if followed by a suitable spring crop (e.g. EF6, EG5) beetle banks (EF7, Skylark only) and Skylark plots (EF8) and low intensity grassland options (EL02-EL03, Yellow Wagtail only) and few of these are popular options. The target for Lapwing was classed as not achievable for all 'probable' options. Lapwing is however increasing, so the relatively high score in Fig. A5.6 is a reflection of the almost complete lack of options that are tailored to suit breeding Lapwings in ELS (although there are specific Lapwing options in HLS, e.g. HF17). The results therefore suggest that ELS options may contribute little to the current recovery.

Corn Bunting first year survival rate scores poorly, suggesting that there are not sufficient options to affect this parameter alone. However, this result was more to do with the large declines and the underlying demographic parameters, than the availability of appropriate options per se. Other species that have experienced less severe declines, but have similar requirements for survival, namely seed rich habitats over winter, were forecast to have achievable targets. For example, targets for Reed Bunting FPA were often classified as possibly achievable, but the targets for a second key parameter, S_{FY}, were always achievable. For Corn Bunting, NA was also identified as a key parameter limiting population growth in this species and the targets for this option seem far more achievable. Unlike other field nesting species, Corn Bunting will nest in tall vegetation and is potentially served by more options (e.g. field corner management) than, for example, Yellow Wagtail. Therefore, for both of these species, there do appear to be certain options that will be able to reverse population declines.

The decline of Starling is driven by first year survival, suggesting food in winter is the limiting factor. For this species there are in fact a large number of options that may deliver winter food, but many of these are grassland options for which are knowledge of the certainty of delivery is lacking, hence they are classified as having 'potential' effects. If further research demonstrates that these do deliver, then ELS may achieve population recovery.

There was often disagreement in the achievability of targets when comparing 'probable' and 'potential' effects of ELS options. For example, there were five species in Table A5.7a where the targets for 'probable' effects were not achievable, but where targets for 'potential' effects were achievable. This suggests that in these species, there are several options that, based on ecological general knowledge, could provide benefits, but where there is currently no good evidence. This was particularly the case with grassland options that are often whole-field (e.g. low input pastures) and therefore cover a potentially large area. However, for many species considered here, the research has largely been within arable landscapes and therefore the discrepancy between 'probable' and 'potential' scenarios reflects a lack of research in grass-dominated agriculture.

This report has followed the approach of Siriwardena & Vickery (2002) and considered relatively recent population trends from 1990 onwards. In the majority of species considered, declines in population began before 1990, but the long-term trends have continued. However, consideration of longer-term trends may have altered the forecasts for several species because key parameters were adjusted based on the long-term trend (Siriwardena & Vickery 2002). As declines were typically more severe post-1990, the increase in key parameters required to result in population increase would have been correspondingly higher in a number of species. From this point of view, the achievability of targets could be considered to be biased in favour of positive forecasts (i.e. targets more likely to be achievable when considering post-1990 trends). Tree Sparrow is likely to be the species where the period over which the population trend is considered has had the greatest effect on the results, as this species showed pre-1990 declines of over 90%, but the trend has been marginally positive post-1990 (Table A5.1). If we consider the 95% decline between 1979 and 2004 (Baillie et al. 2007), then the 'probable' scenario in Table A5.7 would have an unachievable target and the 'potential' scenario would have a possibly achievable target.

Model assumptions

A number of key assumptions underlie the model and the approach taken.

1. *The key parameter is correctly identified* – Many of the species considered have been exhaustively studied and there is general consensus in the ornithological literature about the key parameters that have driven many of the declines. We assume in this research that these parameters are therefore those that are appropriate to target to try and increase population sizes. However, even in species such as the Skylark, which has been subject to a very large amount of work, we still now very little about survival due to the lack of ringing recovery data for this species. Post-fledging survival (S_{PF}) in particular is poorly known in most species. In no case was S_{PF} identified as a key parameter, but could be due to a lack of knowledge of this variable, rather than a reflection that it is not important. The approach here has identified key parameters on the basis of existing evidence. If evidence came to light that other parameters were key in dictating population trends in the future, then there is no reason why the approach taken here could not be modified to include this extra information.

2. *Other parameters do not vary in parallel* – The approach considered effects on individual parameters, where other (non-key) parameters were held constant in the model. This is an inevitably simplified approach, but it enables easily interpretable measures of effects through options acting specifically on individual key parameters and therefore which demographic rates are likely to form the best targets for effective conservation action. There are likely to be multiple effects for several ELS options. For example, options designed to provide seed-rich plants for over-winter survival of granivorous species may also enhance invertebrate populations in the breeding season and therefore may affect productivity. The modelling approach adopted was modified to incorporate a simple overall increase of 1% in non-key parameters which gave a reasonable indication of the effects of potential broad-scale effects of options on demographic parameters (e.g. Tables A5.5 & A5.8). A more complex modelling approach, where several parameters are varied simultaneously, could be developed. However, the lack of knowledge of the inter-dependence of demographic factors and the difficulties in interpreting such models would in all likelihood mean that little added value could be gained by the additional complexity of the analytical approach.

3. *Proportion of population approximates to proportion of farmland area* – This assumption effectively assumes that birds are distributed evenly across the landscape with respect to ELS options. Whilst this is not likely to be strictly true for any species considered, for common widely distributed species (e.g. Kestrel, Skylark, Yellowhammer) the models will provide a reasonable 'average' scenario. The fact that a species has a limited geographic range would not in itself violate the assumption, so long as the options were distributed within that range in proportion to the national distribution. However, it seems likely that such biases will increase as a species' geographic range gets smaller. For example, it seems unlikely that ELS options applied in the restricted ranges of Corn Buntings or Turtle Dove will be representative of the national average. Currently, however, these estimates are the best available. This modelling approach could easily be adapted to consider geographic variations in the future.

4. *The frequency distribution of option uptake does not change as the uptake of the scheme increases* – This assumption applies to calculations involving forecasts assuming 70% uptake of ELS (Tables A5.7b & A5.8b). If small and large farm holdings had the same frequency distribution of options, any change in the ratio of small to large holdings would not matter, so we the assumption is justified. In fact, we know from the uptake analysis undertaken for the Environmental Stewardship evaluation that there were differences between farm types in the frequency distribution of options, though farm size

was not analysed in this regard. Thus, we need to bear in mind that if the ratio of farm types entering the scheme changes, this could affect the pattern of option uptake nationally, and hence the proportion of holding numbers and area providing habitat resources for each species.

5. *Option effect operates at the farm holding level* – The ELS option database available was not able to provide areas of specific options, only the area of farm holdings that had those options. Therefore, the analyses assume that effects of ELS options operate at the farm level. Without much evidence on the actual effects of ELS options, it is difficult to determine whether this assumption was valid. Skylark and Grey Partridge were the only species considered where evidence of effects of ELS options on demographic parameters existed. For Grey Partridge, conservation headlands do seem to confer wider benefits at the farm level (Sotherton et al. 1993). For Skylarks, the evidence for the efficacy of Skylark plots was only considered at the level of cereal fields (Morris et al. 2007), although it seems perhaps unlikely that such small-scale options could have wider benefits. Indeed, this latter point may be crucial when considering individual options. However, in the majority of cases, the effective option area was determined by considering combinations of options that may have benefited a given parameter. From this point of view, the assumption of farm level effects is probably reasonable, although further research into the larger-scale effects of specific options would be welcome.

6. *Option effect is at maximum efficiency* – There is an implicit assumption in the modelling approach used not only in the effect of a given option, but that the option will operate at its maximum efficiency. There is no provision in the modelling approach for varying the effect of options, yet it seems likely that (i) not all options will be implemented according to best practice guidelines and (ii) that option efficacy will vary geographically (e.g. in response to landscape, climate or soil type). However, the information does not yet exist to incorporate such variability into the models. Further research into the variation of option effect under different conditions, and into the between-farmer variation in adhering to option management guidelines, would facilitate development of models that explicitly incorporate option effect variability.

7. *There are no effects of density-dependence* **-** It is likely that demographic parameters will vary according to the population density. For example, survival may be reduced when competition for food is increased. Such effects are undoubtedly important, but they have not been incorporated into the modelling approach used here. Any such effects are likely to be strongest at very high or very low densities. As the modelling approach is based on achieving a small increase in population size (of 1%) and because the models are based on real, national estimates of demographic rates and so should not produce extreme predictions (Siriwardena & Vickery 2002), the assumption is probably justified.

The above listed assumptions may all have effects on the conclusions reached about the forecast achievability of ELS options to increase population size in Tables A5.6-10 and Figure A5.6. Table A5.11 summarises whether each of the above six assumptions is likely to make the target required rates to increase population size more or less achievable. For example, the assumption that only a single parameter at a time is affected (Assumption 2) is likely to produce less achievable targets, because increases in several parameters at once will have a greater effect on population increase. On balance, Table A5.11 suggests that the assumptions made have tended to make forecasts more optimistic: three assumptions tend to push the targets towards more achievable and only one tends to push the target towards less achievable. Three assumptions have effects on the forecast targets that are unknown. Therefore, it seems likely that relaxing these assumptions would serve to make the overall forecast more pessimistic.

Conclusions

This analysis represents a novel approach in assessing how much habitat is required to deliver population recovery in relation to current and predicted uptake of ELS. The approach should be viewed as a guide to assess the likelihood of delivery of population increase and therefore it may be more informative to consider the broad patterns, rather than the results of each individual species. The two key findings in this respect are: (i) the lack of certainty of delivery through grassland options – this reflects a lack of research which is to some extent already being addressed through a number of Defra-NE funded projects; and, (ii) the lack of uptake of in-field options and perhaps to a lesser extent, the more complex/demanding field margin and boundary options. Over and above these broad patterns, we consider four species, Turtle Dove, Yellow Wagtail, Lapwing and Linnet, to be poorly served by ELS. For Turtle Dove, key habitats that could provide seed-rich habitats in the breeding season such as conservation headlands had very poor uptake. Yellow Wagtail and Lapwing both require similar in-field nesting habitat options that are unpopular in terms of uptake. For Linnet however, poor forecast delivery by ELS is largely a result of the uncertainty of the value of grassland options.

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Table A5.1 Population growth rates (PGR) and adjusted demographic parameter estimates used to produce population models that predict future BBS/CBC trajectories continuing with the same trend as found for 1990-2005 in the absence of any demographic changes. * no trend available from BBS.

Species	PGR	SAD	SFY	SJV	SPF	FPA	NA
Kestrel	0.999	0.548		0.257		3.50	1.00
Grey Partridge	0.955	0.415	0.415		0.300	8.60	1.00
Lapwing	1.006	0.655		0.430		1.63	1.00
Stock Dove	1.005	0.440		0.330		1.25	3.00
Woodpigeon	1.026	0.644		0.594		1.27	1.00
Turtle Dove	0.941	0.590	0.400		0.850	1.30	1.60
Skylark	0.983	0.630		0.245		1.45	2.00
Yellow Wagtail	0.962	0.552	0.470		0.510	2.77	1.25
Whitethroat	1.021	0.389	0.279		0.815	2.80	2.00
Jackdaw	1.021	0.700		0.310		2.07	1.00
Rook*		0.780	-	0.300	-	1.70	1.00
Starling	0.949	0.568	0.365		0.383	3.63	1.50
Tree Sparrow	1.007	0.405		0.305		3.03	1.30
Greenfinch	1.030	0.440	0.390		0.670	2.27	2.00
Goldfinch	1.023	0.408	0.382		0.700	2.32	2.00
Linnet	0.980	0.320	0.280		0.840	2.48	2.25
Yellowhammer	0.980	0.536	0.529		0.470	1.45	2.50
Reed Bunting	0.999	0.500	0.410		0.610	1.99	2.00
Corn Bunting	0.960	0.530	0.440		0.700	2.23	1.25

FPA for Woodpigeon refers to fledged young per pair rather than per attempt because the data input into the model for Woodpigeon were in this form (S&V Table A5.3).

Table A5.2. The key demographic rates required to achieve 1.01 population growth for FBI species. The baseline estimate is from Table A5.1.

Species	**Key parameter**	**Rate required**	**Baseline estimate**	**% change required**
Kestrel	FPA	3.600	3.50	3
	S_{JV}	0.264	0.257	3
Grey Partridge	FPA	9.558	8.60	11
Lapwing	FPA	1.651	1.63	1
Stock Dove	S_{JV}	0.304	0.33	none†
Woodpigeon	FPA	0.968	1.27	none†
Turtle Dove	NA	1.900	1.60	19
Skylark	NA	2.140	2.00	7
Yellow Wagtail*	NA	1.380	1.250	10
Whitethroat	S_{FY}	0.272	0.279	none†
Jackdaw	FPA	2.000	2.07	none†
Rook	FPA	1.530	1.70	none†
Starling	S_{FY}	0.424	0.365	16
Tree Sparrow	S_{JV}	0.307	0.305	1
Greenfinch**	S_{FY}	0.390	0.375	none†
Goldfinch	S_{FY}	0.371	0.382	none†
Linnet	FPA	2.572	2.48	4
Yellowhammer	S_{FY}	0.556	0.529	5
Reed Bunting	FPA	2.04	1.99	2
	S_{FY}	0.420	0.410	2
Corn Bunting	NA	1.398	1.25	11
	S_{FY}	0.492	0.440	11

† Population increase already greater than 1%.
* Key parameter was listed as '?' in S&V Table A5.4. This value updated by J. Gilroy (pers. comm.).
** No key parameter given in S&V Table A5.4, but here it is assumed the key parameter is S_{FY} in common with other granivores.

Table A5.3. The magnitude of the key parameter(s) required to achieve 1% population growth when 90%, 50% and 10% of the population is affected by the increased demographic rate. FBI species with a population growth rate of less than 1.01 (Table A5.1) are included. Numbers in parentheses indicate the % increase required from the baseline estimate (see Table A5.2). n/a = survival rate required > 1.

Species	**Key parameter**	**90%**	**50%**	**10%**
Kestrel	FPA	3.605 (<1)	3.691 (5)	4.453 (27)
	S_{JV}	0.265 (3)	0.271 (5)	0.327 (27)
Grey Partridge	FPA	9.665 (12)	10.516 (22)	18.182 (111)
Lapwing	FPA	1.654 (1)	1.672 (3)	1.842 (13)
Turtle Dove	NA	1.934 (21)	2.201 (38)	4.605 (188)
Skylark	NA	2.155 (8)	2.279 (14)	3.393 (70)
Yellow Wagtail	NA	1.394 (12)	1.509 (21)	2.546 (59)
Starling	S_{FY}	0.430 (18)	0.483 (32)	0.954 (161)
Tree Sparrow	S_{JV}	0.307 (1)	0.309 (1)	0.327 (7)
Linnet	FPA	2.582 (4)	2.664 (7)	3.401 (37)
Yellowhammer	S_{FY}	0.559 (6)	0.584 (10)	0.803 (52)
Reed Bunting	FPA	2.04 (3)	2.09 (5)	2.48 (25)
	S_{FY}	0.421 (3)	0.430 (5)	0.511 (25)
Corn Bunting	NA	1.414 (13)	1.545 (24)	2.727 (118)
	S_{FY}	0.498 (13)	0.545 (24)	0.960 (118)

Table A5.4 Maximum key parameters used for each species with PGR<1.01 derived from the literature. (The number of decimal places is given according to the source reference).

Spp	Key parm	Value	Source
Kestrel	FPA	3.88	Shrubb 1993 (NRS data 1950-87)
	S_{JV}	0.4	Shrubb 1993 (after Village)
Grey Partridge	FPA	14.6	Potts 1986 (max. annual mean of studies in Table 3.3)
Lapwing	FPA	2.78	Shrubb 1990 (max. brood size in tillage)
Turtle Dove	NA	2.9	Browne & Aebischer 2004 (after Murton 1968 in a pre-decline study)
Skylark	NA	2.74	Delius 1965 (sand dune population)
Yellow Wagtail	NA	2	Gilroy PhD thesis
Starling	S_{FY}	0.614	Maximum value in Siriwardena et al. 1998 (Table 5.4)
Tree Sparrow	S_{JV}	0.40	S_{FY} available from Siriwardena et al. 1998. Assume S_{PF} is average for granivores = 0.66 (so SJV = 0.601 * 0.66 = 0.4)
Linnet	FPA	2.98	Moorcroft & Wilson 2000 (maximum from Table A5.2)
Yellowhammer	S_{FY}	0.630	Maximum value +1SE in Siriwardena et al. 1998 (Table A5.4)
Reed Bunting	FPA	2.74	Peach et al. (1999)
	S_{FY}	0.538	Maximum value in Siriwardena et al. 1998 (Table A5.4)
Corn Bunting	NA	3	Donald et al. 1994 (after Walpole-Bond 1938 Birds of Sussex)
	S_{FY}	0.538	No estimate available so Reed Bunting S_{FY} used

Table A5.5. The minimum proportion of the population that could result in population growth in the subsequent year if the maximum key parameter was reached. n/a = proportion > 1 required (i.e. the maximum key parameter is below that required to achieve population growth when the proportion = 1).

Species	**Key parameter**	**Proportion required**	**Proportion required with 1% overall increase**
Kestrel	FPA	0.25	<0.01
	S_{JV}	0.04	<0.01
Grey Partridge	FPA	0.16	0.12
Lapwing	FPA	0.02	<0.01
Turtle Dove	NA	0.22	0.17
Skylark	NA	0.18	0.08
Yellow Wagtail	NA	0.18	0.10
Starling	S_{FY}	0.26	0.17
Tree Sparrow	S_{JV}	<0.01	<0.01
Linnet	FPA	0.18	0.05
Yellowhammer	S_{FY}	0.30	0.05
Reed Bunting	FPA	0.05	<0.01
	S_{FY}	0.07	<0.01
Corn Bunting	NA	0.09	0.05
	S_{FY}	0.53	0.33

Table A5.6. The percentage of the population (= % farm area) serviced by ELS options that are likely to affect the key parameter and the level of the key parameter required to result in 1% annual population growth. If the parameter required exceeds the maximum parameter (i.e. % change from max is positive) then the target is considered unrealistic to achieve. If parameter required exceeds 25% of the current estimate, the target is defined as ‘POSSIBLE’.

(a) Probable effect on key parameter

Species	**Key parm.**	**% area affected**	**Parameter required**	**% change (baseline)**	**% change (max)**	**Achievable target**
Kestrel	FPA	31.5	3.8	9	-2	YES
	S_{JV}	33.5	0.28	9	-30	YES
Grey Partridge	FPA	24.1	12.5	45	-14	POSSIBLE
Lapwing	FPA	0				NO
Turtle Dove	NA	1.5				NO
Skylark	NA	10.2	3.4	70	24	NO
Yellow Wagtail*	NA	3.8	5.5	340	175	NO
Starling	S_{FY}	23.4	0.62	70	1	NO
Tree Sparrow	S_{JV}	14.2	0.32	5	-20	YES
Linnet	FPA	1.0				NO
Yellowhammer	S_{FY}	14.2	0.73	38	16	NO
Reed Bunting	FPA	1.8				NO
	S_{FY}	14.2	0.48	17	-14	YES
Corn Bunting	NA	14.9	2.25	80	-25	POSSIBLE
	S_{FY}	14.4	0.82	86	52	NO

(b) Potential effect on key parameter

Species	Key parm.	% area affected	Parameter required	% change (baseline)	% change (max)	Achievable target
Kestrel	FPA	34.7	3.78	8	-3	YES
	S_{JV}	35.6	0.27	5	-32	YES
Grey Partridge	FPA	34.8	11.4	33	-20	POSSIBLE
Lapwing	FPA	28.4	1.68	3	-39	YES
Turtle Dove	NA	30.1	2.59	61	-11	POSSIBLE
Skylark	NA	33.6	2.4	20	-12	YES
Yellow Wagtail*	NA	28.2	1.71	37	-14	POSSIBLE
Starling	S_{FY}	33.9	0.54	48	-12	POSSIBLE
Tree Sparrow	S_{JV}	29.4	0.31	2	-13	YES
Linnet	FPA	30.2	2.79	12	-7	YES
Yellowhammer	S_{FY}	32.5	0.61	15	-3	YES
Reed Bunting	FPA	27.0	2.2	11	-19	YES
	S_{FY}	22.7	0.46	12	-18	YES
Corn Bunting	NA	33.6	1.7	36	-43	POSSIBLE
	S_{FY}	29.5	0.62	41	15	NO

Table A5.7. The minimum proportion of the population that could result in population growth in the subsequent year if the maximum key parameter was reached, the proportion of farmland covered by ELS options that will probably increase the key parameter and the proportion that will potentially increase the key parameter. Each ‘probable’ and ‘potential’ estimate is classified according to whether the proportion required represents an achievable target, where green = achievable, orange = possibly achievable and red = not achievable, given the parameter estimate required relative to the maximum (see Table A5.6).

(a)

Species	**Key parameter**	**Proportion required**	**Probable**	**Potential**
Kestrel	FPA	0.25	🟩 0.32	🟩 0.35
	S_{JV}	0.04	🟩 0.34	🟩 0.36
Grey Partridge	FPA	0.16	🟧 0.24	🟧 0.35
Lapwing	FPA	0.02	🟥 0.00	🟩 0.28
Turtle Dove	NA	0.22	🟥 0.01	🟧 0.30
Skylark	NA	0.18	🟥 0.10	🟩 0.34
Yellow Wagtail	NA	0.18	🟥 0.04	🟧 0.28
Starling	S_{FY}	0.26	🟥 0.23	🟧 0.34
Tree Sparrow	S_{JV}	<0.01	🟩 0.14	🟩 0.29
Linnet	FPA	0.18	🟥 0.01	🟩 0.30
Yellowhammer	S_{FY}	0.30	🟥 0.14	🟩 0.33
Reed Bunting	FPA	0.05	🟥 0.02	🟩 0.27
	S_{FY}	0.07	🟩 0.14	🟩 0.23
Corn Bunting	NA	0.09	🟧 0.14	🟧 0.34
	S_{FY}	0.53	🟥 0.15	🟥 0.30

(b) As above for predicted ELS if there is 70% uptake nationally

Species	Key parameter	Proportion required	Probable	Potential
Kestrel	FPA	0.25	🟩 0.59	🟩 0.65
	S_{JV}	0.04	🟩 0.63	🟩 0.67
Grey Partridge	FPA	0.16	🟩 0.45	🟩 0.65
Lapwing	FPA	0.02	🟥 0.00	🟩 0.53
Turtle Dove	NA	0.22	🟥 0.03	🟧 0.57
Skylark	NA	0.18	🟧 0.19	🟩 0.63
Yellow Wagtail	NA	0.18	🟥 0.07	🟩 0.53
Starling	S_{FY}	0.26	🟧 0.44	🟧 0.64
Tree Sparrow	S_{JV}	<0.01	🟩 0.27	🟩 0.55
Linnet	FPA	0.18	🟥 0.02	🟩 0.57
Yellowhammer	S_{FY}	0.30	🟥 0.27	🟩 0.61
Reed Bunting	FPA	0.05	🟥 0.03	🟩 0.51
	S_{FY}	0.07	🟩 0.27	🟩 0.43
Corn Bunting	NA	0.09	🟧 0.28	🟩 0.63
	S_{FY}	0.53	🟥 0.27	🟩 0.55

Table A5.8 The proportion of the population that would need to increase the mean key parameter to reach the required rate to achieve population increase (Table A5.1) when other demographic parameters also increase by 1%. Other details as per Table A5.7.

(a)

Species	Parameter	Proportion required	Probable	Potential
Kestrel	FPA	<0.01	0.32	0.35
	S_{JV}	<0.01	0.34	0.36
Grey Partridge	FPA	0.12	0.24	0.35
Lapwing	FPA	<0.01	0.00	0.28
Turtle Dove	NA	0.17	0.01	0.30
Skylark	NA	0.08	0.10	0.34
Yellow Wagtail	NA	0.10	0.04	0.28
Starling	S_{FY}	0.17	0.23	0.34
Tree Sparrow	S_{FY}	<0.01	0.14	0.29
Linnet	FPA	0.05	0.01	0.30
Yellowhammer	S_{FY}	0.05	0.14	0.33
Reed Bunting	FPA	<0.01	0.02	0.27
	S_{FY}	<0.01	0.14	0.23
Corn Bunting	NA	0.05	0.14	0.34
	S_{FY}	0.33	0.15	0.30

(b) As above for 70% ELS uptake nationally.

Species	Parameter	Proportion required	Probable	Potential
Kestrel	FPA	<0.01	0.59	0.65
	S_{JV}	<0.01	0.63	0.67
Grey Partridge	FPA	0.12	0.45	0.65
Lapwing	FPA	<0.01	0.00	0.53
Turtle Dove	NA	0.17	0.03	0.57
Skylark	NA	0.08	0.19	0.63
Yellow Wagtail	NA	0.10	0.07	0.53
Starling	S_{FY}	0.17	0.44	0.64
Tree Sparrow	S_{FY}	<0.01	0.27	0.55
Linnet	FPA	0.05	0.02	0.57
Yellowhammer	S_{FY}	0.05	0.27	0.61
Reed Bunting	FPA	<0.01	0.03	0.51
	S_{FY}	<0.01	0.27	0.43
Corn Bunting	NA	0.05	0.28	0.63
	S_{FY}	0.33	0.27	0.55

Table A5.9. Proportion of population at maximum rate required to reach BAP target, with a baseline year of 2003.

Species	**Key parm**	**BAP target**	**Proportion required**	**Proportion required (1%)**
Turtle Dove	NA	Population growth* by 2010	0.10	0.06
Skylark	NA	15% population growth by 2015	0.11	0.05
Tree Sparrow	S_{FY}	50% population growth by 2010	0.20	0.12
Linnet	FPA	15% population growth by 2010	0.19	0.06
Corn Bunting	NA	Population growth* by 2010	0.02	0.01
	S_{FY}		0.36	0.18
Reed Bunting	FPA	15% population growth by 2010	0.08	<0.01
	S_{FY}		0.08	<0.01
Yellowhammer	S_{FY}	15% population growth by 2010	0.35	0.15

* Taken as 1%

Table A5.10. Classification of BAP targets into whether the proportion of area under relevant ELS options is likely to represent an achievable target under probable (Prob) and potential (Pot) effects of ELS. Red = BAP target not achievable, orange = possibly achievable, green = achievable.

		Prob	**Pot**	**Prob**	**Pot**	**Prob**	**Pot**	**Prob**	**Pot**
		Current		**70% uptake**		**Current**		**70% uptake**	
Spp	**Key**					**+1% on parameter estimates**			
Turtle Dove	NA	🟥	🟧	🟥	🟧	🟥	🟧	🟥	🟩
Skylark	NA	🟥	🟩	🟧	🟩	🟧	🟩	🟩	🟩
Tree Sparrow	S_{FY}	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Linnet	FPA	🟥	🟩	🟥	🟩	🟥	🟩	🟥	🟩
Corn Bunting	NA	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
	S_{FY}	🟥	🟥	🟥	🟩	🟥	🟩	🟩	🟩
Reed Bunting	FPA	🟥	🟩	🟥	🟩	🟩	🟩	🟩	🟩
	S_{FY}	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Yellowhammer	S_{FY}	🟥	🟥	🟥	🟩	🟥	🟩	🟩	🟩

Table A5.11. A summary of the key assumptions underlying the modelling approach and the likely effect that each assumption has on the forecast achievability of ELS uptake to reach the required target parameter and therefore result in population increase.

Assumption	**Effect on achievability of target**
1. *The key parameter is correctly identified*	Unknown
2. *Other parameters do not vary in parallel*	Less achievable
3. *Proportion of population approximates to proportion of farmland area*	Unknown
4. *The frequency distribution of option uptake does not change as the uptake of the scheme increases*	Unknown
5. *Option effect operates at the farm holding level*	More achievable
6. *Option effect is at maximum efficiency*	More achievable
7. *There are no effects of density-dependence*	More achievable

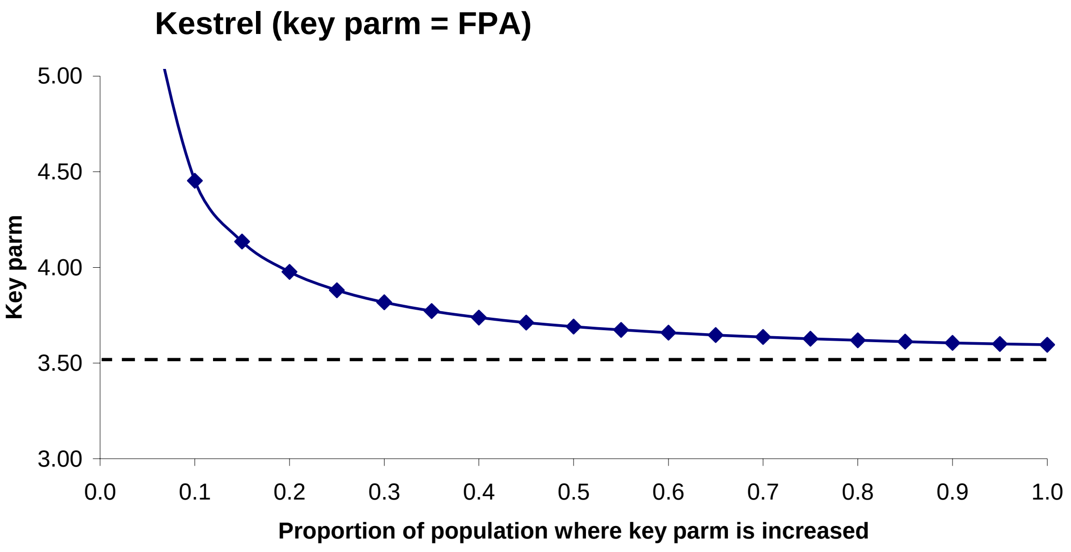

Figure. A5.1. The magnitude of the key parameter required to achieve 1% population growth, when the proportion of the population where the key parameter is able to be increased is varied. The dashed line is the current estimate of the key parameter. In this example, the species is Kestrel and the key parameter is FPA.

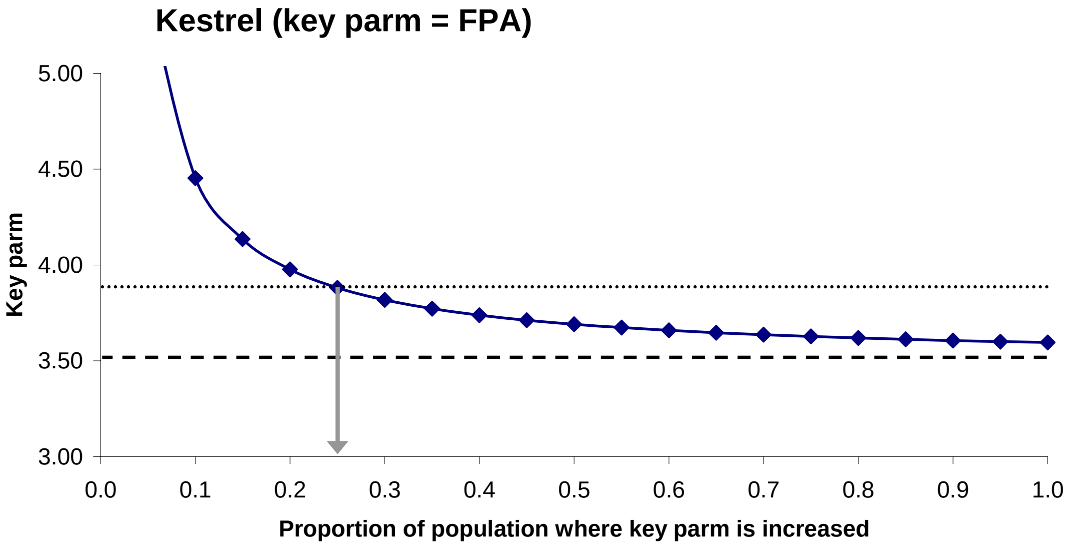

Figure A5.2. The magnitude of the key parameter required to achieve 1% population growth (curve with diamonds). The dashed line is the current estimate of the key parameter, the dotted line is the maximum recorded key parameter (from Table 4). The shaded vertical arrow gives the minimum proportion of the population that would need to be affected by an increase in the key parameter to its maximum value if population growth were to be achieved.

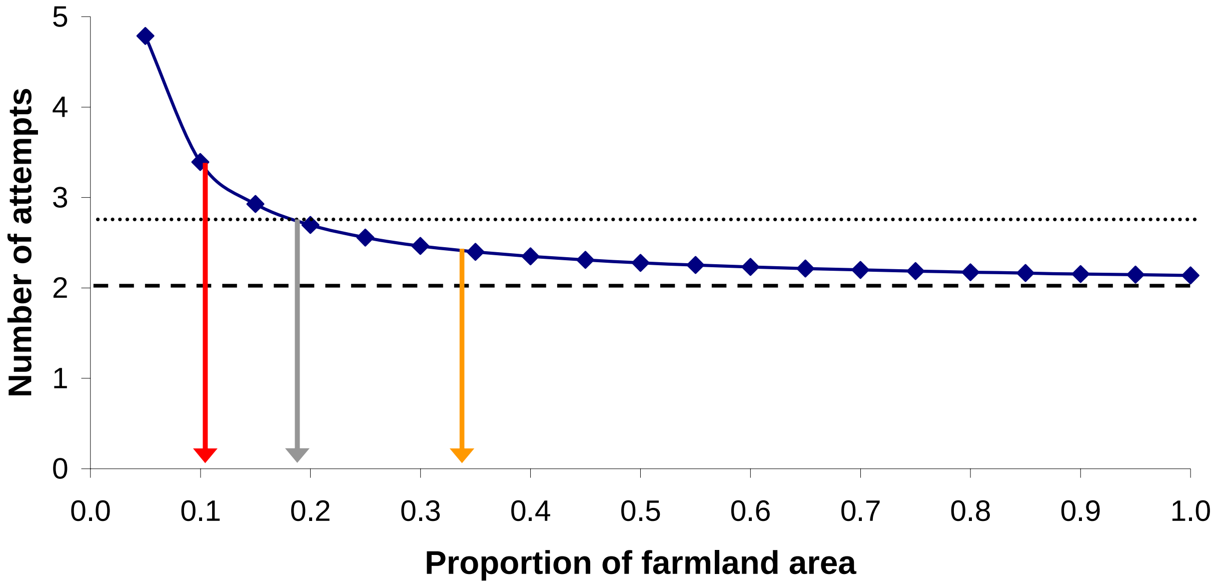

Figure A5.3. The number of attempts required to achieve 1% population growth (curve with diamonds) in Skylark. The dashed line is the current estimate of the key parameter, the dotted line is the maximum recorded key parameter (from Table 4). The shaded vertical arrow gives the minimum proportion of farmland area that would need to be affected by an increase in the key parameter to its maximum value if population growth were to be achieved. The red arrow is the current proportion of farmland area containing ELS options having 'probable' effects on Skylark NA. The orange arrow is the current proportion of farmland area containing ELS options having 'potential' effects on Skylark NA.

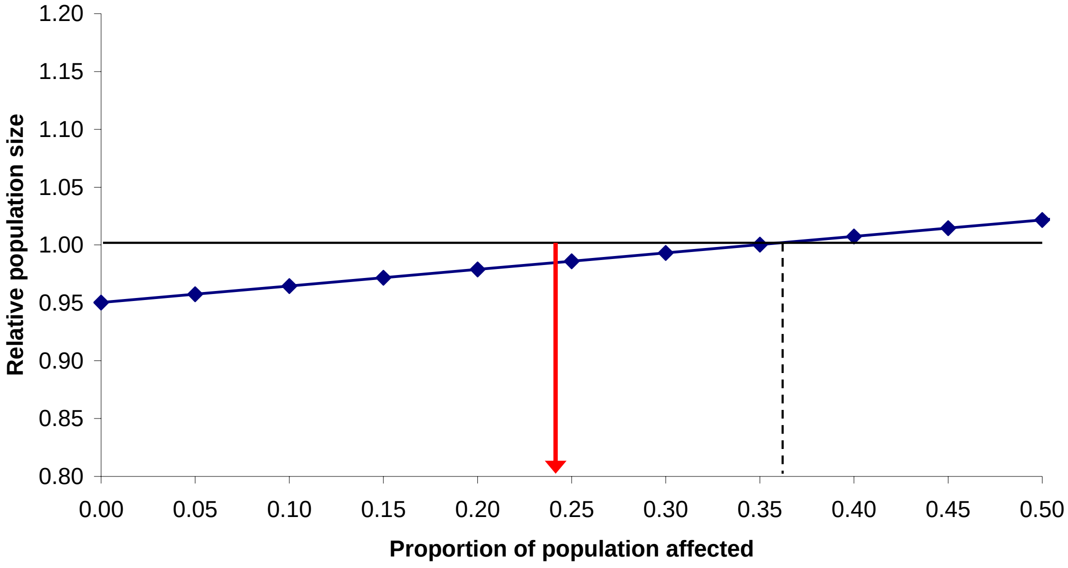

Figure A5.4. The relative population size of Grey Partridge when different proportions of the population are subject to increased S_{PF} . The vertical point represents the point at which the population starts to increase (c. 36%). The red arrow is the current proportion of farmland area containing plots contributing summer food.

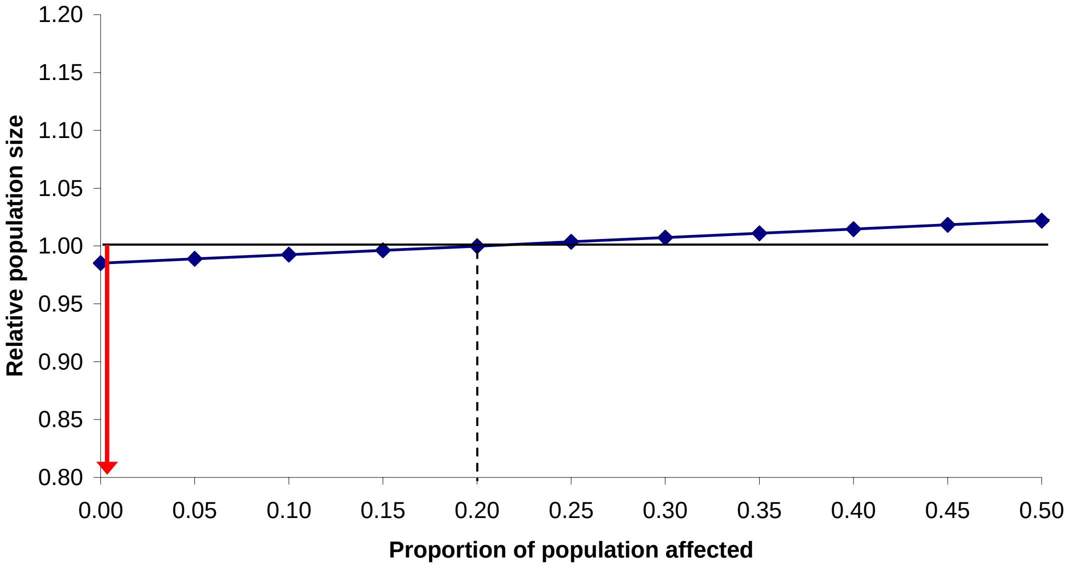

Figure A5.5. The relative population size of Skylark when different proportions of the population are subject to increased FPA. The vertical line represents the point at which the population starts to increase (c. 20%). The red arrow is the current proportion of farmland area containing Skylark plots.

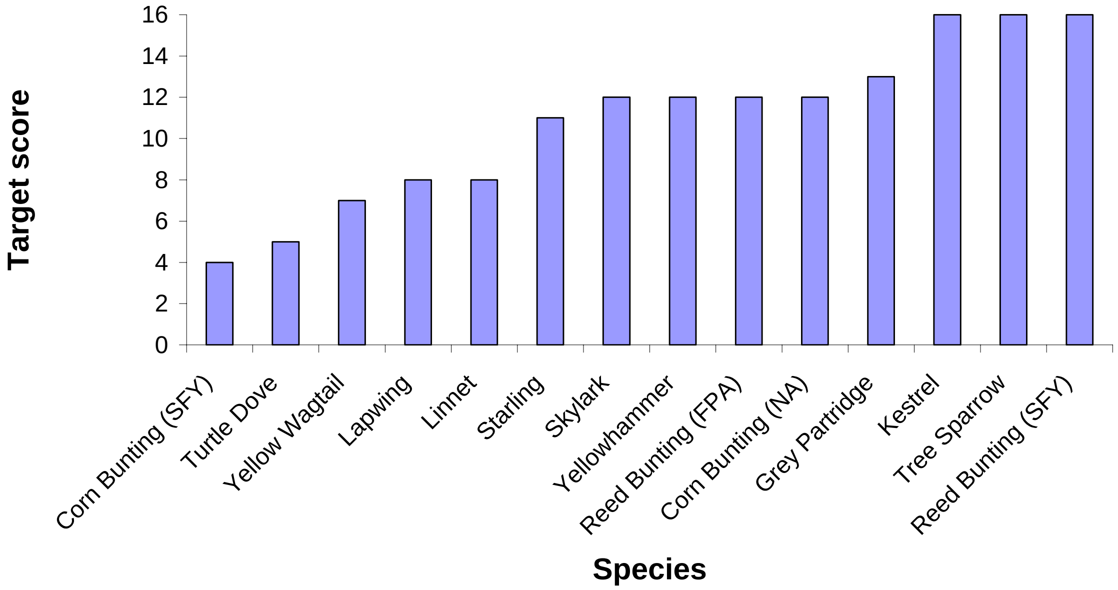

Figure A5.6. Target scores to assess general likelihood of ELS options increasing population growth to at least 1% per year. Scores are derived from Tables 7 & 8, where a forecast achievable target scores 2, a possibly achievable target scores 1 and an unachievable target scores 0. Species are presented in order of ascending score. Note that Kestrel had two key parameters (S_{JV} and FPA), both of which achieved a score of 16.

Appendix I. Additional results for S_{AD} and S_{ALL}.

Table AI1 The rates required to achieve 1% population growth for FBI species where S_{AD} or S_{ALL} is the key parameter. The baseline estimate is from Table A5.1. S_{ALL} is derived from Table A5.1 and eqn. 2 (where S_{FY} and S_{PF} were available) or eqn. 3 (where only S_{JV} was available).

Species	Key parameter	Rate required	Baseline estimate	% change required
Stock Dove	S_{AD}	0.391	0.44	none†
	S_{ALL}	0.351	0.385	none†
Whitethroat	S_{AD}	0.373	0.389	none†
	S_{ALL}	0.308	0.334	none†
Starling	S_{AD}	0.629	0.568	10.74
	S_{ALL}	0.494	0.467	5.78
Tree Sparrow	S_{AD}	0.409	0.405	0.99
	S_{ALL}	0.340	0.355	none†
Greenfinch***	S_{AD}	0.440	0.417	none†
	S_{ALL}	0.401	0.415	none†
Goldfinch	S_{AD}	0.390	0.408	none†
	S_{ALL}	0.385	0.395	none†
Yellowhammer	S_{AD}	0.559	0.536	4.29
	S_{ALL}	0.555	0.533	4.13
Reed Bunting	S_{AD}	0.512	0.500	2.40
	S_{ALL}	0.456	0.455	0.22
Corn Bunting	S_{AD}	0.581	0.530	9.62
	S_{ALL}	0.511	0.485	5.36

† Population increase already greater than 1%

*** none in S&V Table A5.4, but assume survival in common with other granivores

Table AI2. Maximum key parameters (source is the same for S_{FY}/S_{JV} in Table A5.4), and the minimum proportion of the population that could result in population growth in the subsequent year if the maximum key parameter was reached. n/a = required rate not achieved when 100% of the population subject to increase in key parameter. Also presented are results when other parameters are also subject to increases of 1%.

Spp	**Key parm**	**Max value**	**Proportion**	**Proportion (1%)**
Starling	S_{AD}	0.806	0.26	0.17
	S_{ALL}		0.12	0.07
Tree Sparrow	S_{AD}	0.376	<0.01	<0.01
	S_{ALL}		<0.01	<0.01
Yellowhammer	S_{AD}	0.613	0.30	<0.01
	S_{ALL}		0.62	0.55
Reed Bunting	S_{AD}	0.542	0.29	<0.01
	S_{ALL}		<0.01	<0.01
Corn Bunting	S_{AD}	0.58	n/a	0.48
	S_{ALL}		0.35	0.21

APPENDIX 6 ASSESSING THE RISK OF INCREASED BLOCK CROPPING OF WINTER WHEAT AND OIL SEED RAPE AND THE GROWTH OF BIOFUEL CROPS ON SET-ASIDE TO FARMLAND BIRD POPULATIONS

INTRODUCTION

A range of land-use change scenarios have been predicted in light of changes to UK and European agricultural policy (Dwyer *et al.* 2006). Given that agriculture has been a major driver of ecosystem change and biodiversity loss globally (Donald *et al*. 2001, Green *et al*. 2005) and that, in the UK and Europe, these impacts have been largely been driven by policy that supported production-linked subsidies (Chamberlain *et al*. 2000, Donald *et al*. 2002), it is important that the potential impacts of these changes are explored. Here we use a recently published biodiversity risk assessment framework (Butler *et al*. 2007) to predict the impact of two of these land-use change scenarios: a) predicted declines in the area sown to (spring) barley and sugar beet in favour of winter wheat and oil seed rape, with increased block cropping of these simplified rotations and b) increased growth of biofuel crops on set-aside land. This risk assessment approach links species' national population trends to field-scale changes in land-use management and allows the likely impact of proposed agricultural changes to be assessed. We use it to predict both species' population growth rate and conservation status in the resultant agricultural landscapes.

The risk assessment framework adopts a trait-based approach to risk assessment and was developed using farmland birds as a model system. It draws on a matrix of ecological requirements covering the diet, foraging habitat and nesting habitat of 62 bird species recorded as having some association with farmland habitats. The likely impact of an agricultural change is quantified by assessing the extent to which it detrimentally impacts the ecological requirements of each species. The framework takes into account species' vulnerability to change, as defined by their degree of specialisation or niche breadth, and their reliance on farmland habitat, as quantified by expert panel. The risk score generated by the framework therefore reflects the proportion of a species' ecological requirements affected by an agricultural change, with higher scores attributed to species demonstrating a greater proportion of affected requirements (see Butler *et al.* 2007 for a detailed description of the risk assessment framework).

To validate the approach, the environmental hazards associated with six key components of past agricultural intensification in the UK – the switch from spring to autumn sowing, increased agrochemical inputs, loss of non-cropped habitats, land drainage, the switch from hay to silage and the increased intensity of grassland management – were identified. Based on their impact on the quantity and quality of food and habitat in the agricultural landscape, risk scores were calculated for each of these changes and then summed to provide an overall assessment of the impact of past intensification on each farmland bird species. The risk score generated by this validation process was significantly related to both the annual rate of population growth, with higher risk assessment scores associated with species with negative population growth rates and therefore experiencing population decline ($F(1, 49) = 11.4$, $P = 0.001$), and the probability of being listed in these conservation status categories (Mean score ± 1 SE for species on red list = 6.6 ± 0.8, amber list = 4.9 ± 0.8, green list = 2.2 ± 0.4; Ordinal logistic regression: $\chi^2 = 25.4$, $P < 0.001$) (Butler *et al*. 2007). Parameter estimates from these regression models can be used to predict the likely impact of future changes to agricultural systems or management practices on farmland bird populations.

Whilst determining the potential detrimental impacts (hazards) associated with an agricultural change may be a relatively straight-forward component of risk assessment, determining the level of exposure to these hazards is much more difficult because it will be determined by the spatial congruence of land-use change and species' distribution. The validation of the trait-based risk assessment approach only assessed UK-wide land-use changes and effectively assumed that the UK population of vulnerable species, i.e. those species whose ecological requirements coincide with the hazards associated with the agricultural change, was potentially exposed to those hazards. For the assessment of land-use changes reported here we have assumed similar scales of change, i.e. that the land-use change will occur nationwide and that the entire population of vulnerable species will be affected. If the land-use change is likely to be spatially restricted, and only a proportion of the population of vulnerable species are therefore likely to be exposed to the associated hazards, these predictions need to be interpreted accordingly.

METHODS

Identifying hazards associated with the land-use change scenarios

The risk assessment framework assumes that the major sources of risk to UK farmland birds will be reduced food abundance and reduced nesting success. An agricultural change will impact food abundance if it causes a change in foraging habitat availability and/or a change in prey abundance in the existing foraging habitat. It will impact nesting success if it causes a change in nesting habitat availability and/or a reduction in nest success in the existing nesting habitat. Expert opinion was used to identify which ecological requirements of farmland birds were likely to be affected by a) predicted declines in the area sown to (spring) barley and sugar beet in favour of winter wheat and oil seed rape, with increased block cropping of these simplified rotations and b) increased growth of biofuel crops on set-aside land. Both scenarios are likely to lead to a reduction in the availability of over-wintered stubbles in the agricultural landscape. Any over-wintered stubbles that do persist in the landscape can be expected to have reduced weed seed availability under these scenarios. The temporal changes in vegetation structure over the course of the summer will also lead to a reduction in summer foraging habitat and nest site availability due to reduced access (Table A6.1). Whilst the risk assessment framework makes no distinction between arable and pastoral habitats, four species – Snipe *Gallinago gallinago*, Curlew *Numenius arquata*, Oystercatcher *Haematopus ostralegus* and Corncrake *Crex crex* – are identified as being solely associated with pastoral systems during the summer. Although these species are recorded as foraging and nesting in crop habitats in the summer, the loss of summer crop habitat and crop nest sites associated with these land-use change scenarios will not affect these species as they will only occur in arable systems. Therefore, no score is allocated to these four species for these two hazards. No other species are restricted solely to arable or pastoral systems in either summer or winter.

Table A6.1. Key hazards for farmland bird populations associated with both an increase in block cropping of winter wheat or rape and the increased growth of wheat and rape as biofuel crops on set-aside.

Hazard	Temporal period affected
Reduction in crop habitat	Summer & Winter
Reduction in crop seeds	Winter
Reduction in crop nest sites	Summer

Characterisation of risk to farmland birds

The risk to each species for each land-use change scenario, assuming UK-wide implementation, was characterised by calculating risk scores based on exposure to the hazards outlined in Table A6.1 (see Butler *et al*. 2007 for full details of risk score calculation methodology). Accurately determining the impact of these changes requires that the condition of the landscape into which they will be introduced is taken into account. Species scores from the risk assessments were therefore combined with their score from the validation process, which characterise responses to current landscape conditions, to characterise risk in the resultant landscapes. These risk scores were used to calculate the predicted annual population growth rate and conservation status of each species in the agricultural landscape following a) declines in the area sown to (spring) barley and sugar beet in favour of winter wheat and oil seed rape, with increased block cropping of these simplified rotations (Table A6.2), b) increased growth of biofuel crops on set-aside land (Table A6.2) and c) both declines in the area sown to (spring) barley and sugar beet in favour of winter wheat and oil seed rape, with increased block cropping of these simplified rotations, and increased growth of biofuel crops on set-aside land (Table

A6.3) using the following parameter estimates derived from the validation process (Butler *et al.* 2007):

1) Annual population growth rate = 0.008 – 0.004*risk score
2) Probability of being red listed, p(red) = 0.5 + (1/π) arctan (-3.457 + 0.458*risk score)
3) Probability of being amber listed, p(amber) = 0.5 + (1/π) arctan (-1.545 + 0.458*risk score) – p(red),
4) Probability of being green listed, p(green) = 1 – (p(red) + p(amber))

Table A6.2 Predicted annual growth rate and conservation status of farmland bird species following either an increase in block cropping of winter wheat and rape or increased growth of biofuel crops on set-aside. Note that the key hazards associated with these two scenarios are the same so their predicted impact on farmland bird populations is the same.

Species	Current annual growth rate		Current conservation status		Risk score[2]	Predicted annual growth rate[3]	Predicted conservation status[4]
	Actual	Predicted[1]	Actual	Predicted			
Acrocephalus schoenobaenus	-0.004	0.002	Green	Green	1.67	0.002	Green
Alauda arvensis	-0.025	-0.033	Red	Red	14.50	-0.046	Red
Anas platyrhynchos	0.030	-0.003	Green	Green	3.83	-0.006	Green
Anthus pratensis	-0.012	-0.016	Amber	Amber	8.25	-0.023	Red
Burhinus oedicnemus		-0.025	Red	Red	11.00	-0.033	Red
Buteo buteo	0.047	-0.004	Green	Green	3.75	-0.006	Green
Carduelis cannabina	-0.023	-0.027	Red	Red	12.17	-0.037	Red
Carduelis carduelis	0.010	-0.001	Green	Green	2.38	-0.001	Green
Carduelis chloris	0.006	0.001	Green	Green	2.25	0.000	Green
Carduelis flavirostris		-0.011	Red	Amber	6.50	-0.016	Amber
Carduelis spinus	-0.025	0.004	Green	Green	1.17	0.004	Green
Certhia familiaris	0.002	0.004	Green	Green	1.00	0.004	Green
Circus pygargus		-0.018	Amber	Red	9.00	-0.025	Red
Columba oenas	0.020	-0.020	Amber	Red	10.00	-0.029	Red
Columba palumbus	0.020	-0.004	Green	Green	4.13	-0.007	Amber
Corvus corone corone	0.020	-0.003	Green	Green	3.27	-0.004	Green
Corvus frugilegus	0.016	-0.021	Green	Red	10.00	-0.029	Red
Corvus monedula	0.019	-0.002	Green	Green	3.35	-0.004	Green
Coturnix coturnix		-0.022	Red	Red	10.00	-0.029	Red
Crex crex		-0.014	Red	Amber	6.00	-0.014	Amber
Cuculus canorus	-0.018	0.003	Amber	Green	1.56	0.002	Green
Emberiza cirlus		-0.035	Red	Red	15.00	-0.048	Red
Emberiza citrinella	-0.024	-0.029	Red	Red	13.00	-0.040	Red
Emberiza schoeniclus	-0.021	-0.003	Red	Green	2.88	-0.003	Green
Erithacus rubecula	0.012	0.002	Green	Green	1.71	0.002	Green
Falco tinnunculus	-0.015	-0.016	Amber	Amber	7.50	-0.020	Red
Fringilla coelebs	0.008	0.000	Green	Green	2.75	-0.002	Green
Gallinago gallinago	-0.041	-0.010	Amber	Amber	5.00	-0.011	Amber
Gallinula chloropus	0.006	0.000	Green	Green	2.22	0.000	Green
Haematopus ostralegus	0.030	-0.011	Amber	Amber	5.50	-0.012	Amber
Lagopus lagopus	0.006	0.000	Amber	Green	2.64	-0.002	Green
Lullula arborea		-0.003	Red	Green	3.25	-0.004	Green
Miliaria calandra	-0.071	-0.038	Red	Red	16.50	-0.053	Red
Motacilla alba	0.014	-0.011	Green	Amber	6.00	-0.014	Amber
Motacilla flava	-0.029	-0.022	Amber	Red	9.50	-0.027	Red
Numenius arquata	-0.022	-0.011	Amber	Amber	5.50	-0.012	Amber

Parus caeruleus	0.007	0.004	Green	Green	1.00	0.004	Green
Parus major	0.013	0.004	Green	Green	1.00	0.004	Green
Passer domesticus	-0.042	-0.002	Red	Green	2.87	-0.003	Green
Passer montanus	-0.091	-0.013	Red	Amber	6.75	-0.017	Amber
Perdix perdix	-0.063	-0.024	Red	Red	10.83	-0.032	Red
Phylloscopus collybita	0.002	0.005	Green	Green	0.67	0.005	Green
Phylloscopus trochilus	-0.020	0.005	Green	Green	0.67	0.005	Green
Pica pica	0.024	-0.002	Green	Green	3.35	-0.004	Green
Prunella modularis	-0.014	-0.001	Amber	Green	2.39	-0.001	Green
Pyrrhula pyrrhula	-0.027	0.002	Red	Green	1.50	0.002	Green
Streptopelia decaocto	0.029	0.001	Green	Green	2.17	0.000	Green
Streptopelia turtur	-0.047	-0.006	Red	Green	4.25	-0.008	Amber
Sturnus vulgaris	-0.035	-0.024	Red	Red	11.00	-0.033	Red
Sylvia atricapilla	0.025	0.004	Green	Green	1.17	0.004	Green
Sylvia borin	-0.003	0.005	Green	Green	0.83	0.005	Green
Sylvia communis	-0.006	-0.001	Green	Green	2.50	-0.001	Green
Sylvia curruca	0.001	0.003	Green	Green	1.25	0.003	Green
Tetrao tetrix		-0.004	Red	Green	3.96	-0.007	Green
Troglodytes troglodytes	0.014	0.001	Green	Green	1.83	0.001	Green
Turdus iliacus		0.004	Amber	Green	1.44	0.003	Green
Turdus merula	-0.008	0.001	Green	Green	1.88	0.001	Green
Turdus philomelos	-0.024	-0.005	Red	Green	3.79	-0.006	Green
Turdus pilaris		0.004	Amber	Green	1.44	0.003	Green
Turdus viscivorus	-0.014	-0.004	Amber	Green	3.69	-0.006	Green
Tyto alba		-0.012	Amber	Amber	6.50	-0.016	Amber
Vanellus vanellus	-0.017	-0.037	Amber	Red	15.00	-0.048	Red

[1] Calculated from validation risk score using parameter estimates in equation 1) above.

[2] This is the risk for the resultant landscape following either an increase in block cropping of winter wheat and rape or increased growth of biofuel crops on set-aside. It is the sum of the species' validation score, representing risk in the current landscape, and the specific risk for the proposed change.

[3] Parameter estimates detailed in equation 1) above.

[4] Parameter estimates detailed in equations 2), 3) and 4) above.

Table A6.3. Predicted annual growth rate and conservation status of farmland bird species following both an increase in block cropping of winter wheat and rape and increased growth of biofuel crops on set-aside.

Species	**Current annual growth rate**		**Current conservation status**		**Risk score[2]**	**Predicted annual growth rate[3]**	**Predicted conservation status[4]**
	Actual	**Predicted[1]**	**Actual**	**Predicted**			
Acrocephalus schoenobaenus	-0.004	0.002	Green	Green	1.67	0.002	Green
Alauda arvensis	-0.025	-0.033	Red	Red	18.00	-0.059	Red
Anas platyrhynchos	0.030	-0.003	Green	Green	4.67	-0.009	Amber
Anthus pratensis	-0.012	-0.016	Amber	Amber	10.00	-0.029	Red
Burhinus oedicnemus		-0.025	Red	Red	13.00	-0.040	Red
Buteo buteo	0.047	-0.004	Green	Green	4.25	-0.008	Amber
Carduelis cannabina	-0.023	-0.027	Red	Red	15.00	-0.048	Red
Carduelis carduelis	0.010	-0.001	Green	Green	2.38	-0.001	Green
Carduelis chloris	0.006	0.001	Green	Green	2.58	-0.002	Green
Carduelis flavirostris		-0.011	Red	Amber	8.00	-0.022	Red
Carduelis spinus	-0.025	0.004	Green	Green	1.17	0.004	Green
Certhia familiaris	0.002	0.004	Green	Green	1.00	0.004	Green

Circus pygargus		-0.018	Amber	Red	11.00	-0.033	Red
Columba oenas	0.020	-0.020	Amber	Red	12.50	-0.038	Red
Columba palumbus	0.020	-0.004	Green	Green	5.13	-0.011	Amber
Corvus corone corone	0.020	-0.003	Green	Green	3.63	-0.006	Green
Corvus frugilegus	0.016	-0.021	Green	Red	12.20	-0.037	Red
Corvus monedula	0.019	-0.002	Green	Green	3.90	-0.007	Green
Coturnix coturnix		-0.022	Red	Red	12.00	-0.036	Red
Crex crex		-0.014	Red	Amber	6.00	-0.014	Amber
Cuculus canorus	-0.018	0.003	Amber	Green	1.67	0.002	Green
Emberiza cirlus		-0.035	Red	Red	18.50	-0.061	Red
Emberiza citrinella	-0.024	-0.029	Red	Red	16.00	-0.051	Red
Emberiza schoeniclus	-0.021	-0.003	Red	Green	2.88	-0.003	Green
Erithacus rubecula	0.012	0.002	Green	Green	1.71	0.002	Green
Falco tinnunculus	-0.015	-0.016	Amber	Amber	8.50	-0.024	Red
Fringilla coelebs	0.008	0.000	Green	Green	3.25	-0.004	Green
Gallinago gallinago	-0.041	-0.010	Amber	Amber	5.25	-0.012	Amber
Gallinula chloropus	0.006	0.000	Green	Green	2.22	0.000	Green
Haematopus ostralegus	0.030	-0.011	Amber	Amber	6.00	-0.014	Amber
Lagopus lagopus	0.006	0.000	Amber	Green	3.06	-0.003	Green
Lullula arborea		-0.003	Red	Green	3.50	-0.005	Green
Miliaria calandra	-0.071	-0.038	Red	Red	20.50	-0.068	Red
Motacilla alba	0.014	-0.011	Green	Amber	7.00	-0.018	Red
Motacilla flava	-0.029	-0.022	Amber	Red	11.00	-0.033	Red
Numenius arquata	-0.022	-0.011	Amber	Amber	6.00	-0.014	Amber
Parus caeruleus	0.007	0.004	Green	Green	1.00	0.004	Green
Parus major	0.013	0.004	Green	Green	1.00	0.004	Green
Passer domesticus	-0.042	-0.002	Red	Green	3.21	-0.004	Green
Passer montanus	-0.091	-0.013	Red	Amber	7.75	-0.021	Red
Perdix perdix	-0.063	-0.024	Red	Red	13.17	-0.041	Red
Phylloscopus collybita	0.002	0.005	Green	Green	0.67	0.005	Green
Phylloscopus trochilus	-0.020	0.005	Green	Green	0.67	0.005	Green
Pica pica	0.024	-0.002	Green	Green	3.90	-0.007	Green
Prunella modularis	-0.014	-0.001	Amber	Green	2.39	-0.001	Green
Pyrrhula pyrrhula	-0.027	0.002	Red	Green	1.50	0.002	Green
Streptopelia decaocto	0.029	0.001	Green	Green	2.58	-0.002	Green
Streptopelia turtur	-0.047	-0.006	Red	Green	4.75	-0.010	Amber
Sturnus vulgaris	-0.035	-0.024	Red	Red	13.25	-0.041	Red
Sylvia atricapilla	0.025	0.004	Green	Green	1.17	0.004	Green
Sylvia borin	-0.003	0.005	Green	Green	0.83	0.005	Green
Sylvia communis	-0.006	-0.001	Green	Green	2.50	-0.001	Green
Sylvia curruca	0.001	0.003	Green	Green	1.25	0.003	Green
Tetrao tetrix		-0.004	Red	Green	4.58	-0.009	Amber
Troglodytes troglodytes	0.014	0.001	Green	Green	1.83	0.001	Green
Turdus iliacus		0.004	Amber	Green	1.75	0.001	Green
Turdus merula	-0.008	0.001	Green	Green	1.88	0.001	Green
Turdus philomelos	-0.024	-0.005	Red	Green	4.17	-0.008	Amber
Turdus pilaris		0.004	Amber	Green	1.75	0.001	Green
Turdus viscivorus	-0.014	-0.004	Amber	Green	4.25	-0.008	Amber
Tyto alba		-0.012	Amber	Amber	7.50	-0.020	Red
Vanellus vanellus	-0.017	-0.037	Amber	Red	18.00	-0.059	Red

[1] Calculated from validation risk score using parameter estimates in equation 1) above.

[2] This is the risk for the resultant landscape following an increase in block cropping of winter wheat and rape and increased growth of biofuel crops on set-aside. It is the sum of the species' validation score, representing risk in the current landscape, and the specific risks for both the proposed changes.

[3] Parameter estimates detailed in equation 1) above.

[4] Parameter estimates detailed in equations 2), 3) and 4) above.

Whilst the predicted conservation status category for a species may not change under these scenarios, the confidence with which it is assigned to a category may vary. To assess these more subtle effects the number of species predicted to be assigned to each status category (i.e. the sum of probabilities across the 62 species) in the current and resultant landscapes can be compared (Table A6.4).

Table A6.4. The number of bird species predicted to be assigned to each conservation status category in the current agricultural landscape, a landscape where either an increase in block cropping of winter wheat and rape or increased growth of biofuel crops on set-aside have occurred (single scenario) and a landscape where both these changes have occurred (both scenarios).

	Red	Amber	Green
Current landscape	16.78	16.00	29.22
Single scenario	20.05	14.88	27.08
Both scenarios	22.27	14.37	25.36

SUMMARY AND CONCLUSIONS

Both an increase of block cropping of winter wheat and rape in place of (spring) barley and sugar beet and an increase in the growth of biofuel crops on set-aside are expected to lead to a reduction in the availability of over-wintered stubbles in the agricultural landscape, with any over-wintered stubbles that do persist in the landscape having reduced weed seed availability. The temporal changes in vegetation structure over the course of the summer will also lead to a reduction in summer foraging habitat and nest site availability due to reduced access. Since the hazards associated with each scenario are the same, they are both predicted to have the same level of impact if introduced into the agricultural landscape independently. Forty-two of the species included in these analyses, including 16 of the 19 species in the farmland bird index, either forage and/or nest in the cropped area of arable fields and are therefore susceptible to exposure to these hazards. These species are therefore likely to experience reduced population growth rates under these scenarios. If either of these land-use changes occurred, three species Meadow pipit, Wood pigeon and Kestrel are predicted to be re-classified to a less favourable conservation status (Amber to Red, Green to Amber and Amber to Red respectively). If both an increase in block cropping and an increase in the growth of biofuel crops took place, the same subset of species would be vulnerable but the predicted increase in risk to these species, and therefore degree of detrimental change in population growth rate, would be double that if either the scenarios was realised independently. If both land-use changes occurred, seven species are predicted to be re-classified to a less favourable conservation status, with Meadow pipit, Kestrel and Barn Owl all predicted to become red-listed. Again it should be highlighted that these predictions assume UK-wide land-use change and therefore exposure of the whole population of vulnerable species to these hazards.

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